PDA DIAGNOSIS OF THERMOSTATS

BACKGROUND

The present invention pertains to thermostats and

5   particularly to the control of air management systems. More

particularly, it pertains to the testing and diagnosis of

programmable thermostat operation in conjunction with the air

management systems.

Commissioning, testing and diagnosis of thermostat systems

10   may be time consuming and confusing. The thermostat

configuration must first be understood and then the

commissioning process may be run through valid operational modes

with inputs and set points temporarily manipulated while waiting

for the delays built into the controller to verify operation.

15   The setting and adjusting of air management system thermostats,

especially programming thermostats, to control air conditioning,

heating, humidity, volume of moved air, and the like, may have

settings and conditions that determine which equipment is turned

on or off, and for when and what duration. Many commercial and

20   residential places may have complex and confusing controls for

air management systems which have features such as programmable

thermostats. Some proprietors may obtain a programmable control

system for controlling heating and cooling in their buildings.

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However, they may have frustrations with the adjusting and

operating those kinds of systems and often stop trying to take

advantage of certain control features of the systems. An

installer may initially set a system up and get it operating

5   satisfactorily; however, the adjusting and setting the system

may not be easy for the new recipient or owner of the system

because of the apparent complexity, user unfriendliness, and the

lack of convenient and sufficient time to learn, set and adjust

various parameters of the system for controlling, for instance,

10   heating, ventilation and air conditioning (HVAC).

SUMMARY

The present invention minimizes the issues of complexities,

user unfriendliness, and the amount of time and inconvenience

15   involved in commissioning, testing and diagnosing a thermostat

system. A personal digital assistant (PDA) may be used

significantly easing such activities. PDA-based on line

diagnostics may automatically discover the thermostat

configuration, turn off normal controller delays, temporary

20   override sensor inputs and set points, and verify proper output

action including the monitoring the discharge air temperature

for the resulting temperature behavior based on the equipment

stages activated. Problems discovered are reported,

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automatically recorded and the original operating parameters can be restored. This means that less expertise may be required the technicians sent to install and trouble shoot thermostat installations.

5   The diagnostic application may minimize the issues of complexities, user unfriendliness, and the amount of time and convenience involved in setting up, adjusting and controlling an air management system, such as an air handling and conditioning system. Additionally, it is possible for one at a convenient

10   time at any place to set and adjust a thermostat, controller or computer having numerous parameters and options that may be selected for a desired operation of the air management system. One does not need to be at the thermostat, controller or computer of the air management system to configure, set or

15   adjust the parameters of it. The parameters may include, but not be limited to, temperatures, humidity, sensor selection, volume of air movement, fan or air mover behavior such as continuous or intermittent and speed, the percentage of added fresh air, stages of cooling and heating at various zones,

20   control of heat pumps, heaters and air conditioners, modes of occupied, unoccupied or standby of respective spaces in a building, for day and night, between specific times, at certain days, for certain buildings at specific locations. The system

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may enable one to easily and conveniently achieve these tasks
with an interfacing of a PDA (viz., a personal digital
assistant) to the control system. These tasks may be
accomplished on a PDA in an armchair remote from the facility
5   with the air management system.

A program with configuration information may be uploaded to
the PDA from a controller of an air handling and conditioning
system, such as the HVAC. Such controller may be similar to a
programmable thermostat having adjustment and settings for
10 controlling the parameters of the system. All of the items that
need to be done for configuring, setting, adjusting and
controlling a system via the thermostat, controller or computer
may be done on a PDA at any time at a location as desired,
possibly remote from the building having the system. Whether at
15 the office, home or other place, one may configure, set and
adjust, among other things, with the PDA, parameters and actions
of a controller relative to various air management systems at
different facilities. Programmed configurations, settings,
adjustments and the like may be done with the PDA. Then one may
20 take the PDA and go to the various thermostats, controllers,
computers or other air management system control devices and
upload the programs specific to the respective systems. These
may be placed in memory. One interface connection for the

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uploading and downloading between the PDA and the thermostat,

controller or computer of the air management system may be an

infrared (IR) connection. One may obtain a PDA that is readily

available in stores, such as a Palm™, or the like, and take it

5   to a thermostat, controller, computer or control module of the

air management system and upload a program, including the

configuration and the settings the system. Then one may deal

with various configurations, settings, adjustments and related

activities as desired relative to the parameters of the air

10   management system and then download any changes to the

respective thermostat, controller, computer or control module of

the system.

The interfacing between the PDA or similar commercially

available device and the controller or thermostat may also be

15   done via radio frequency communications (such as Bluetooth or

Wi-Fi), electrical lines such as the telephone, or optical fiber

systems. The internet, Ethernet, or intranet in its various

aspects may be used for interfacing between the PDA and the

controller or thermostat. Other forms of interfacing between

20   the PDA and the system may be implemented.

A technical person, installer, representative or

technician, trained for configuring, setting and adjusting

control mechanisms of air management system thermostats, may go

to various buildings such as stores, factories or offices and do

control changes for the air management systems of those places.

The control mechanism of the air management system of each place

may have its own specific configuration and settings which may

5   be different from the others. The technician may go from place

to place and download specific configurations and settings with

the PDA very quickly and efficiently to the air management

system thermostats at these places.

Even though there are many ways that programmable

10   thermostats, controllers, control mechanisms, computers, control

modules or their equivalents (hereinafter each of these may be

referred to as a "thermostat") of air management systems may be

communicated with, relative to the setting and configuration

inputs, the PDA using the infrared interface is inexpensive and

15   easily adaptable. Many individuals have a PDA of one kind or

another which may have an infrared or direct connection port.

No modification is of these devices needed to use them with the

present system. One merely may go to the respective thermostat

of the PDA and upload a program that has the appropriate

20   protocol, configuration and setting information of the system.

Then one may enter the desired settings, adjustments and

schedule information relative to the control of the air

management system. The information is presented on the PDA in a

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clear and step by step instructive manner. And as indicated

above, the PDA may contain numerous and differing configurations

and settings applicable to specific systems at different places.

Anyone with a PDA or the like may participate in this program.

5   However, there may be security measures requiring codes or other

permission granting procedures so that the integrity of the

control of air management systems may be maintained.

An installer's configuring of high end programmable

commercial thermostats has become very complex due to all of the

10   features that can be implemented by low cost microprocessors.

There is a trade-off between the ease of use and the complexity

of the user interface. Configuring might be done only once by

the installer and then usually is not required again for the

life of the thermostat, whereas for settings and adjustments,

15   the operator interface may be used periodically and should be as

user friendly as possible. In the past, the installer

configuration process was very obscure and error prone since it

had been a secondary function of the operator user interface

that partially reused some of the operator interface features in

20   an obscure secondary manner so as to attempt reducing costs

associated with the device. This approach was time consuming

and error prone, had to be repeated for each installation, and

was still costly.

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By removing the thermostat configuration installer
interface from the thermostat operator interface to a PDA, as in
the present system, the following benefits are noted. There is
an easy to use configuration process with context checking on

5   previous selections so only valid options are presented and
errors cannot be made, and also easy to use navigation of
thermostat configuration screens. Novice users may be directed
to the next appropriate parameter entry screen based on the
context of previous configuration selections. Configurations

10   can be done ahead of time and downloaded quickly at installation
time. Similar configurations do not have to be repeated on
every device but simply recalled from storage and downloaded.
The PDA based thermostat configuration application may generate
a code that represents the raw configuration. This code can be

15   recorded (for example on paper) and entered by hand quickly into
the thermostat keyboard if a PDA is not available at the job
site. There is context dependent control loop tuning. The
thermostat PID (viz., proportional, integral and derivative
gains) control loop tuning parameters may be automatically

20   adjusted as a function of equipment type, number of output
stages, output type (modulating or discrete), the HVAC process,
and other factors as desired.

A PDA and its interfacing with the thermostat of an air management system may also be used for automatic testing, checkout, analysis and diagnosis of the system. Testing and trouble-shooting a complex fully featured commercial thermostat

5 may be time consuming and confusing since the configuration must first be understood and then the operation must be run through valid modes with inputs and set points temporarily manipulated, plus waiting for the delays built into the controller, to verify operation.

10 Commissioning a complex fully featured commercial thermostat also may be time consuming and confusing. The thermostat configuration should first be understood and then the commissioning process may be run through valid operational modes with inputs and set points temporarily manipulated while waiting

15 for the delays built into the controller to verify operation.

The PDA based online diagnostics may automatically discover the thermostat configuration, turn off normal controller delays, temporarily override sensor inputs and set points, verify proper output action including monitoring the discharge air temperature

20 for the resulting temperature behavior based on the equipment stages activated. Problems discovered may be reported, automatically recorded and the original operating parameters may be restored. This means that less expertise may be required by

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the technicians sent to install and trouble shoot thermostat

installations.

A thermostat may be designed to interface to a PDA or other

handy low cost device with an easy wire, IR or RF connection

5   that will allow it do fast, accurate automatic thermostat

testing, diagnosing and trouble-shooting. The PDA may

automatically obtain the thermostat configuration, turn off

normal controller delays, temporarily override sensor inputs and

set points, and verify proper output action including monitoring

10   the entry and discharge air temperatures for the resulting

temperature behavior based on the equipment stages activated.

Problems discovered can be reported, automatically recorded and

the original operating parameters can be restored. This means

that less expertise is required by the technicians sent to

15   install and trouble shoot thermostats. Smart status reporting

simplifies the thermostat installers' field-commissioning task

of selecting and monitoring the appropriate real time data. The

smart status report content and layout may be based on a theme

of management by exclusion. The report generator may respond to

20   real time parameter and data changes in the thermostat

environment. There may be a possible web-based system in which

the installer or technician need not to go out to the site of

the air management system. The installer or technician may be

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able to diagnose and can fix the system over the internet, Ethernet or the like. However, using the PDA and its infrared interface may be as or more reasonable than the configuring or diagnosing a thermostat, its sub-base and corresponding air

5   management system. PDA configuring and diagnostics may be utilized in residential homes as well as commercial facilities.

Programmable commercial thermostat systems have also been gaining in popularity due to the energy savings associated with programmable schedules and set points. Most small commercial

10   buildings with one or two zones typically may have rooftop equipment controlled through relay contacts such as heat stage 1, heat stage 2, cooling stage 1, cooling stage 2, and fan. These controls may be interfaced through remote wiring from the zone thermostat to the associated rooftop unit. As commercial

15   thermostat requirements and thermostats become more sophisticated, there may be a need to control heating and cooling coils at control ranges in between specific stage loads. This could be particularly important as chilled water systems and partial load or oversized systems are used. Further, there

20   appears to be a need to control modulating zones and a need for a commercial modulating thermostat that is able to support both traditional staged and modulating outputs.

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This system may solve the problems associated with control

issues by implementing a true analog heating and cooling signal

to be implemented by the roof top control system. Several

enhancements and options exist in the algorithm and thermostat

5   configuration to assist and lead to control of water valves and

oversized heating coils and loads. Under staging conditions,

traditional control algorithm techniques may be used to control

the on/off control to the heating coils, cooling coils and fan.

When used in a modulating configuration, special analog driver

10   circuits may allow the output from the thermostat to provide 4

to 20 milliamps and 2 to 10 volts for direct interfacing for the

control of modulated components. These control parameters are

popular ranges for many modulated dampers and valves used in air

management systems, such as HVACs.

15   The thermostat may contain a software component that allows

automatic configuration of the output actuation type (modulation

and discrete) identified by the sub-base with preset

configuration resistors. The hardware component of the output

actuation may be implemented through an analog interface set

20   from the thermostat. Analog control and interface to the

modulation may be controlled through software algorithm PID and

staging information. If additional heating is desired after a

stage is added at low load, additional supply is available

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through increasing of the analog heating signal. Applications

of this modulating thermostat may be used for boiler firing rate

controls and other energy supply or cooling type equipment.

Through the use of programmable memory, additional algorithms

5   can be developed to apply to a wide range and variety of control

applications besides air management system control.

The present thermostat may provide modulated/analog control

of an air management system and discrete/digital control of the

same or another air management system. This thermostat may

10   provide modulating control of a single stage of heating and/or

cooling. On the other hand, this thermostat may provide

modulating control of multiple stages of heating and cooling.

The modulating output to one cooling or heating stage may result

in an efficient level of output of the controlled stage. If

15   more output is needed from that stage, the thermostat may with

the modulating output call on another stage and control it for

more heating or cooling, so as to maintain the better efficiency

of the first stage. Also, modulated control may result in the

next stage's approaching an efficient level of output. This

20   approach may continue for more output or less output as needed

form the respective stages. The thermostat may provide analog

or digital signals for controlling single or multiple cooling or

heating stages. Humidity control may also be implemented by the

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thermostat and associated air management equipment. A group of

thermostats may be connected to a common communications bus.

Such bus may have a sequencer connected to the bus.

Instructions, software changes, commands, parameters and other

5   information may be communicated among the thermostats and the

sequencer. Operations of the thermostats may be sequenced.

Information about an example sequencer may be disclosed in U.S

Patent number 6,536,678 B2, entitled "Boiler Control System and

Method", issued March 25th, 2003, and by inventor Michael A.

10   Pouchak, which is hereby incorporated herein by reference.

Information about an example humidity controller may be

disclosed in U.S. Patent Application serial number 10/314,604,

entitled "Humidity Controller", filed on December 4th, 2002, and

by inventor Paul C. Wacker, which is hereby incorporated herein

15   by reference. Information about an example HVAC may be

disclosed in U.S. Patent number 5,172,565, entitled "Air

Handling System Utilizing Direct Expansion Cooling", issued

December 22, 1992, and by inventors Richard A. Wruck et al.,

which is hereby incorporated herein by reference.

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BRIEF DESCRIPTION OF THE DRAWING

Figure 1 shows a configuration tool for a thermostat of an

air management system.

Figure 2 shows the configuration tool of Figure 1 in conjunction with a sub-base.

Figures 3a and 3b show screens of a personal digital assistant (PDA) for entering a new thermostat configuration.

5   Figures 4a-4d show PDA screens for selecting an existing configuration and connecting the PDA to the thermostat for uploading the configuration.

Figures 5a-5c reveal screen for downloading a new configuration to the thermostat.

10   Figures 6a-6d are screens that relate to uploading and modifying an existing configuration, and downloading it.

Figures 7a and 7b are screens showing a download and upload connection selection to a thermostat and a room temperature calibrate, respectively.

15   Figures 8a-8e are screens showing a process for connecting to a thermostat, reading information and saving it, and monitoring data.

Figures 9a-9j illustrate steps of reviewing the configuration of a thermostat, making possible changes and

20   saving them.

Figures 10a-10l show the screens and steps for an advanced configuration review, possible modification, and saving of any modification.

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Figures 11a and 11b show screens for selecting units and locking default configuration files.

Figure 12a shows a file command screen.

Figures 12b-12e are screens that show various actions that

5   may be taken relative to a configuration.

Figure 13 relates to setting the time and date of the thermostat being configured.

Figures 14a-14m are screens showing steps for scheduling various temperature set points on different days, selecting fan

10   operation, selecting heating and cooling stages, selecting sensor location, loading the program for a particular facility and saving the current thermostat configuration.

Figures 14n-14r are screens relating to the enabling of partial downloads after the opening screen.

15   Figures 14s-14z are screens pertaining to various override options.

Figure 15 is a flow chart of formation and downloading contractor information to a thermostat.

Figure 16 is a diagram showing the major components and

20   communication channels of the thermostat.

Figure 17 is a block diagram of a modulating thermostat system.

Figure 18 is a block diagram of a networked modulating and non-modulating thermostat system.

Figure 19 is a flow diagram of a modulating sub-base sequence.

5   Figure 20a and 20b show a display and a thermostat assembly with the display and a keyboard.

Figure 21 shows a roof top air management system.

Figure 22 is a context diagram revealing a process structure in a thermostat.

10   Figure 23 is a diagram of a transmit and handshake portion of a communications process of the thermostat.

Figure 24 shows an overview of an algorithm mode relative to the thermostat.

Figures 25a and 25b show details of a function in the 15 algorithm shown in Figure 24.

Figures 26 and 27 reveal the various connections between the thermostat, sub-base and an external device such as a PDA.

Figures 28a-28c show PDA screen steps to attain a commission summary screen of a test and diagnosis of a 20 thermostat system.

Figures 29a-29c show screens for a diagnosis of temperature and other sensors, and set points.

Figure 30 is a screen for a fan check.

Figures 31a-31h are screens showing steps for cooling equipment testing and diagnosis.

Figures 32a-32e show PDA screens for testing heating equipment of the thermostat system.

5   Figure 33 is a flow diagram of an illustrative diagnostic test sequence for a thermostat system.

DESCRIPTION

The system may be an installation and/or configuration tool

10   10 for a programmable thermostat 11, or the like, of an air management system 15, as shown in Figures 1 and 2. Thermostat configuration tool and system 10 may consist of application code and two hardware devices. A PDA application code may be used to configure the thermostat. The first hardware device may be a

15   tool platform 12, that is, a PDA hand held device. The second device may be an RS232 interface module 13 including a connection cable. Sensors 25 may be connected to thermostat 11. Configuration tool and system 10 may provide the following value added features: an armchair thermostat 11 setup; a saving of

20   tested thermostat configurations for reuse; a reduction of configuration errors; a reduction in warranty returns and customer callbacks; an updating of control setpoints (for example room temperature occupied, unoccupied and standby

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setpoints); weekly and holiday schedules; and user defined

default configuration values. A PDA hardware platform is

preferred over a laptop personal computer (PC) 24 for several

reasons including, but not limited to, lower initial cost and

5   smaller size.

An illustrative example of thermostat 11 may be a prototype

programmable thermostat, model T7350, built by Honeywell

International Inc. in Minneapolis, MN. The configuration tool

12 application software and a 10 pin serial interface module may

10   be compatible with the following PDA hardware platforms: Palm™

m105; Palm™ m100; Palm™ Vx Series; Palm™ VII Series; Palm™ III

Series; Palm™ i705; Palm™ Zire71; Palm™ TungstenT; and TRGPro™.

The application code may be compatible with PALM OS™ software

version 3.5.x. "OS" is an operating system of a Palm™ platform.

15   The OS version compatibility may be for all versions greater

than or equal to 3,5x, such as OS 5.2.1. The system may also be

hosted on a Microsoft Windows™ CE OS PDA platform.

Configuration tool serial interface 13 module may be compatible

with the various models and versions of thermostat 11. The

20   thermostat serial interface module may support IR, WiFi,

Bluetooth and other wireless communications media. Thermostat

11 may have serial communications to allow communications with

installer configuration tool 12 and a sub-base 14. Thermostat

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11 may be configured using an installer setup through the

thermostat keys 15 for basic setup functions. Advanced features

may be available through installer configuration tool 12.

    Thermostat configuration tool 12 may be used in the context

5   of the following scenarios. In configuring offline, the user

may arrange and save various named thermostat configurations

with tool 12 disconnected from the thermostat 11. The user may

have the option to note a configuration identification code and

manually set the code using tool or user interface 12. Then

10 interface 12 may connected to a thermostat 11 and air management

system 15 may be configured with an existing named arrangement

of parameters. Configuration tool 12 may read and verify the

existing arrangement of parameters. Virtually all of the

parameters may be changed resulting in a modified or new

15 configuration. Also, the temperature display of thermostat 11

may be calibrated. The user may have an option to save the

modified or new configuration file under another name.

    Tool 12 may be utilized for performing online diagnostics.

For example, tool 12 may be connected to thermostat 11 and

20 diagnostic information such as the thermostat firmware version,

the thermostat hardware version, the sub-base hardware version,

and run time error messages may be read.

The thermostat configuration tool 12 may have a configuration which may include third party PDA hardware platform supporting application software and serial connection cable with the RS232 interface of module 13. The Palm™ PDA, as an illustrative example, may be used in conjunction with the serial interface having connections as noted in the following table 1 showing the terminals for a Palm™ PDA serial connection.

Table 1

Pin #	Signal Name & Direction	Function
1	DO (out)	DTR
2	VCC (out)	+3.30V Palm™ III through a 330 ohm resistor. +4.07V Palm™ V
3	RXD (in)	Receive Data.
4	RTS (out)	Request to send.
5	TXD (out)	Transmit Data.
6	CTS (in)	Clear to send.
7	HS IRQ (in)	Interrupt line for waking the device, Palm OS™ default is to initiate the HotSync process.
8	ID (in)	Peripheral ID line.
9	unused	Not connected
10	SG	Signal Ground

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One may note that pin 10 is located at left as viewed from the back of the Palm™ PDA. The HotSync cradle button shorts pins 2 & 7. Palm™ devices i705, m125, m130 m500, m505, m515 require a 16 pin connector. One may refer to

5   http://www.palmos.com/dev/tech/hardware/palmhardware/electrical_ interface(16-pin)signals.pdf for details regarding the Palm™ 16 pin connector.

Thermostat 11 configuration may be changed or varied according to certain aspects which are provided as an

10 illustrative example in the following tables. There are setup parameters and default values which may be noted. Table 2 may reveal some display/user interface options.

Table 2

Config Option	Default	Min	Max	Res	Units	Description
Degree temperature display	0	0	1	1		Temperature display 0: °F 1: °C
Maximum Occupied Cooling Setpoint stop	85	45	99	1	F	Highest the occupied cooling setpoint can be adjusted. MaxCoolStPt>=OccCl>=OccHt+2 Display Resolution: 1 (F/C)
Minimum Occupied Heating Setpoint stop	55	40	90	1	F	Lowest the occupied heating setpoint can be adjusted. MinHeatStPt<=OccHt<=OccCl-2 Display Resolution: 1 (F/C)
Unoccupied Heat Setpoint	55	40	90	1	F	
Standby Heat Setpoint	67	40	90	1	F	
Standby Heat Setpoint	67	40	90	1	F	
Occupied Heat Setpoint	70	40	90	1	F	
Occupied Cool Setpoint	75	45	99	1	F	

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Standby Cool Setpoint	78	45	99	1	F	
Unoccupied Cool Setpoint	85	45	99	1	F	
Clock format	0	0	1	1		0: 12-hour clock format 1: 24-hour clock format
Keypad lockout level	0	0	2	1		Keypad lockout enable/disable through special keypad sequence. 0: No lockout. 1: Lockout all keys except Temporary Occupied, increase, decrease and information **. 2: Lockout all keys except information **. **Do not allow adjustments on dehumidification high limit setpoint.
System Switch	0	0	3,7	1		0: Auto 1: Cool 2: Heat 3: Emergency Heat 7: Off

Table 3 shows an input/output configuration.

Table 3

Config Option	Default	Min	Max	Res	Units	Description
Remote space temperature sensor	0	0	2	1		0: Local sensor only. 1: Remote sensor only. 2: Network Rm Sensor (Sub-base)
Space humidity sensor	0	0	3	1		0: No space humidity sensor. 1: Local space humidity sensor enabled. 2: Remote space humidity sensor enabled. 3: Network room RH sensor (Sub-base)
Discharge air sensor	0	0	1	1		0: No discharge air sensor. 1: Discharge air sensor enabled.
Outside air sensor	0	0	2	1		0: No outside air sensor. 1: Outside air sensor enabled 2: Network OAT sensor (Sub-base)
Auxiliary contact operation	0	0	3	1		0: Time of day contact. 1: Economizer contact. 2: Dehumidification hot gas bypass contact 3: Simple Dehumidification contacts. Notes: Aux contact not available if heat pump selected and Sub-base #1.
Occupancy Sensor	0	0	2	1		0: No Occupancy sensor. 1: Use Remote Occupancy sensor. 2: Use Network Occupancy sensor (future).

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Table 4 reveals the fan operation options.

Table 4

Config Option	Default	Min	Max	Res	Units	Description
Fan Switch	0	0	1	1		0: On 1: Auto
Fan Operation	0	0	1	1		0: Conventional applications where equipment controls fan operation in heat mode. That is, the plenum switch controls the fan when in heat mode and the Thermostat controls the fan when in cool mode. 1: Electric heat applications where thermostat controls fan operation in heat mode.
Extended fan operation in heating	1	0	1	1		0: No extended fan operation after call for heat ends. 1: Fan operation extended 90 seconds after call for heat ends.
Extended fan operation in cooling	0	0	1	1		0: No extended fan operation after call for cooling ends. 1: Fan operation extended 45 seconds after call for cool ends.

Table 5 shows the control tuning options.

Table 5

Config Option	Default	Min	Max	Res	Units	Description
Cycler Authority	4	2	15	1	R	Thermostat Cycler Authority (Theta).

Table 6 reveals the cooling operation options.

Table 6

Config Option	Default	Min	Max	Res	Units	Description
Cooling Output stages	2	0	4	1		Stages of cooling. 0: No cooling. 1: One cooling stage. 2: Two cooling stages. 3: Three cooling stages. 4: Four cooling stages.
Cooling system response	0	0	1	1	Cph	0: Standard response 3 cph. 1: Fast response 4 cph
Cooling TR	4	1	30	1	R	Cooling proportional gain (deg F)
Cooling IT	2500	0, 10	5000	1	Sec	Cooling integral time (seconds). 0 = disable.
Cooling DT	0	0	3000	1	Sec	Cooling derivative time (seconds). 0 = disable.

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Config Option	Default	Min	Max	Res	Units	Description
Cooling Action	0	0	1	1		Cooling action. Applies only to proportional outputs. 0 = direct acting. 1 = reverse acting
Cooling Lockout	0	0	1	1		0: No OAT lockout 1: cooling locked out if Outdoor air valid and OAT < ClgLockoutSP
Cooling Lockout SP.	35	-40	120	1	F	
DAT Low Limit	45	35	60	1	F	Discharge Air Temperature Low Limit.
Minimum cool recovery ramp rate	3	0	20	1	F/Hr	Minimum cooling recovery ramp rate, 0-36°F/hr.
Min cool OAT	90	-20	100	1	F	Minimum cooling outdoor air temperature
Max cool recovery ramp rate	6	0	20	1	F/hr	Maximum cooling recovery ramp rate
Max cool OAT	70	-20	100	1	F	Maximum cooling outdoor air temperature

Table 7 shows the heating operation options.

Table 7

Config Option	Default	Min	Max	Res	Units	Description
Heating output stages	2	0	3	1		Stages of heating. 0: No heating. 1: One heating stage. 2: Two heating stages. 3: Three heating stages. (Not available if configured for 4 stages of cooling)
Auxiliary heating stages	0	0	2	1		0: No auxiliary heating 1: one stage of auxiliary heat 2: two stages of auxiliary heat
Heating system response	1	0	3	1		0: Standard response 3 cph. 1: Medium response 6 cph. 2: Fast 9 cph 3: Super fast response 20cph
Heating TR	4	1	30	1	R	Heating proportional gain (deg F)
Heating IT	2500	0, 10	5000	1	Sec	Heating integral time (seconds). 0 = disable.
Heating DT	0	0	3000	1	Sec	Heating derivative time (seconds). 0 = disable.
Heating Action	1	0	1	1		Heating action. Applies only to proportional outputs. 0 = direct acting. 1 = reverse acting
Heating Lockout	0	0	1	1		0: no lockout 1: heat locked out if OAT valid and (OAT > HtgLockoutSP)

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	Default	Min	Max	Res	Units	Description
Heating Lockout SP.	70	-40	120	1	F	
DAT High Limit	110	65	140	1	F	Discharge Air Temperature High Limit
Minimum heat recovery ramp rate	5	0	20	1	F/hr	Minimum heating recovery ramp rate
Min heat OAT	0	-20	100	1	F	Minimum heating outdoor air temperature
Maximum heat recovery ramp rate	8	0	20	1	F/hr	Maximum heating recovery ramp rate
Max heat OAT	40	-20	100	1	F	Maximum heating ramp rate outdoor air temperature

Table 8 shows the heat pump options.

Table 8

Config Option	Default	Min	Max	Res	Units	Description
Heat Pump Control	0	0	1	1		0: Conventional Control 1: Heat Pump Control
Heat Pump Reversing Valve	1	0	1	1		0: energize O/B on call for Heat 1: energize O/B on call for Cooling

Table 9 reveals the relative humidity control options.

Table 9

Config Option	Default	Min	Max	Res	Units	Description
RH high limit	65	10	90	1	%	Relative Humidity high limit setpoint.
Dehumidify using minimum ON time	0	0	1	1		0: None 1: Dehumidification using minimum on time
Dehumidify Min On Time	5	5	15	1	min	This is the minimum on time used for if the user chose "Dehumidify Minimum On".
Dehumidify using reset	0	0	1	1		0: None 1: Dehumidification using Room Temperature SetPoint reset
Dehumidify using reheat	0	0	1	1		0: None 1: Dehumidification using reheat
HumTempReset	2	1	5	1	R	Humidity temperature reset The dehumidify reset must be smaller than the occupied zero energy band (ZEB) or standby ZEB.

Table 10 is a list of energy management options.

Table 10

Config Option	Default	Min	Max	Res	Units	Description
Demand limit control bump	3	0	10	1	R	Demand limit control set point bump
Sequential start	0	0	15	1		Delay in 10 second increments. 0 is no delay. Delays start of equipment after power restored to thermostat. For example, setting of 3 is a 30 second delay. 0 - 0 seconds 1 – 10 seconds 2 – 20 seconds .... 15 - 150 seconds

Table 11 indicates the calibration options.

Table 11

Config Option	Default	Min	Max	Res	Units	Description
Temperature display adjustment	0	0	7	1		Room Temperature display adjustment 0: No difference in displayed temperature and actual room temperature. 1: Display adjusts to 1°F (0.6°C) higher than actual room temperature. 2: Display adjusts to 2°F (1.1°C) higher than actual room temperature. 3: Display adjusts to 3°F (1.7°C) higher than actual room temperature. 4: Display adjusts to -4°F (0.6°C) lower than actual room temperature. 5: Display adjusts to –3°F (1.1°C) lower than actual room temperature. 6: Display adjusts to –2°F (1.7°C) lower than actual room temperature. 7: Display adjusts to –1 F lower than actual room temperature.

Table 12 shows the override and bypass options.

Table 12

Config Option	Default	Min	Max	Res	Units	Description
Temporary override duration	2	0	7	1	Hr	Override duration in hours. 0: 1 hour 1: 2 hours .... 7: 8 hours

Table 13 shows a time schedule with default time schedule settings. The time resolution may be one minute. The

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limit may be no more than two occupied or two unoccupied or

two standby events per day.

Table 13

Day	Event	Mode	Time
Sun 0	1		
	2		
	3		
	4		
Mon 1	1	Occupied	8:00AM
	2	Unoccupied	10:00PM
	3		
	4		
Tue 2	1	Occupied	8:00AM
	2	Unoccupied	10:00PM
	3		
	4		
Wed 3	1	Occupied	8:00AM
	2	Unoccupied	10:00PM
	3		
	4		
Thr 4	1	Occupied	8:00AM
	2	Unoccupied	10:00PM
	3		
	4		
Fri 5	1	Occupied	8:00AM
	2	Unoccupied	10:00PM
	3		
	4		
Sat 6	1		
	2		
	3		
	4		
Hol 7	1		
	2		
	3		
	4		

Table 14 shows the daylight savings schedule settings. The

default range may be from the first Sunday in April to the last

Sunday in October.

Table 14

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Config Option	Default	Min	Max	Res	Units	Description
DlsStartDay	33	0	74	1		0: None 1, 2, 3, ... 31, 32: LastDayOfMonth 33: FIRST_SUN 34: FIRST_MON ... 67: FIFTH_SAT ... 74: LAST_SAT
DlsStopDay	68	0	74	1		0: None 1, 2, 3, ... 31, 32: LastDayOfMonth 33: FIRST_SUN 34: FIRST_MON ... 67: FIFTH_SAT ... 74: LAST_SAT
DlsStartMonth	4	0	12	1		0: None 1: Jan, ... 12:Dec Default Value:April
DlsStopMonth	10	0	12	1		0: None 1: Jan, ... 12:Dec Default Value: October

Table 15 relates to holiday schedule settings. This table shows one typical schedule of ten schedules.

Table 15

Config Option	Default	Min	Max	Res	Units	Description
Holiday Schedule Month	0	0	12	1		0: Unprogrammed 1: January 12: December
Holiday Schedule Day	0	0	74	1		0: Unprogrammed 1, 2, 3, ... 31, 32: LastDayOfMonth 33: FIRST_SUN 34: FIRST_MON ... 67: FIFTH_SAT ... 74: LAST_SAT
Holiday duration	0	0	99	1	days	0: No holiday 1: 1 day holiday 99: 99 day holiday

Table 16 is a default holiday schedule. Configuration tool 12 may provide the following default holidays.

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Table 16

Holiday	Month	Day	Duration
New Year's Day	1	1	1
Memorial Day	5	Last Monday	1
Independence Day	7	4	1
Labor Day	9	First Monday	1
Thanksgiving	11	Fourth Thursday	1
Christmas	12	25	1

Table 17 relates to a real time configuration with real

time clock settings.

5   Table 17

Config Option	Default	Min	Max	Res	Units	Description
Clock Year	255	0	175,255	1		Valid range is Jan 1, 2000 to Dec 31, 2175 0: 2000 1: 2001 2: 2002 .... 175: 2175 255: Invalid/Not Used
Clock Month	0	0	12	1		0: UnProgrammed 1: January ... 12: December
Clock Day	0	0	31	1		0: Unprogrammed 1: 1 2: 2 31: 31
Clock Minutes	720	0	1439	1		0: Midnight = first minute of the day 720: noon. 1439: 11:59 p.m
Clock Seconds	0	0	59	1		0: 0 = first second of the minute 1: 1 ... 59: 59 = last second of the minute

10

Configuration tool 12 may calculate a configuration

identification as a function of a selected group of thermostat

11 configuration parameters, using an algorithm. Configuration

tool 12 may display the computed thermostat 11 configuration

15   identification.   There are configuration parameter dependencies.

30

Here are summarized configuration rules governing limits on

parameter data entry and display in the context of thermostat 11

functional sub-base configured inputs, configured outputs and

occupancy mode. There may be a temperature setpoint and mode

5   dependency. Configuration tool default time values may be

initialized based on the context of the user selected occupancy

mode. Table 18 shows default schedule time values. Events 1

and 3 may be either occupied or standby. Events 2 and 4 may be

either standby or unoccupied. It may be that there should be no

10   more than two occupied or two unoccupied events per day.

Table 18

Mode Selected	Default Time
Occupied	8:00AM
Standby	11:30AM
Unoccupied	10:00PM

Table 19 reveals the set point range and resolution.

Setpoint constraints may include MinHeatStPt<=OccHt<=OccCl-2,

15   MaxCoolStPt>=OccCl>=OccHt+2, UnoccHt<=OccHt<=OccCl-2,

UnoccHt<=StdByHt<=StdByCl-2, UnoccCl>=OccCl>=OccHt+2,

UnoccCl>=StdByCl>=StdByHt+2.

Table 19

Config Option	Min	Max	Res	Units
Cooling Setpoint	45	99	1	F
	7	37	1	C
Heating Setpoint	40	90	1	F
	5	32	1	C

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A heat pump configuration screen context rule may be to enable a heat pump configuration if the sub-base type is 1, 2 or 3. A standard control configuration screen context rule may be

5   to enable a standard control configuration if the sub-base type 1, 2, 3 or 4. A dehumidification configuration screen context rule may be to enable if the sub-base type is 3 or 4 and the relative humidity sensor is configured. A variable recovery rate configuration screen context rule may be to enable if the

10   sub-base type is 2, 3 or 4 and the outside air temperature (OAT) sensor is enabled. The relative humidity sensor configuration screen context rule may be to enable if the sub-base type is 3 or 4. The discharge air temperature (DAT) and OAT sensor configuration screen context rule may be to enable if the sub-

15   base type 2, 3 or 4.

Sub-base 1 may be a base wall plate configuration. A total of four relays may be available with the thermostat and sub-base. An auxiliary relay may be configured for an economizer, the time of the day, dehumidification, or an additional stage of

20   heating or cooling. The selections that may be disabled are the relative humidity Sensor, the DAT sensor, the OAT sensor, the occupancy sensor and the remote room sensor. Table 20 shows an installer configuration option for sub-base 1.

Table 20

Installer Configuration Option	Sub-base 1
Heating output stages	1
Cooling Output stages	1
Room humidity sensor	0

Sub-base 2 may be a two heat stage/two cool stage basic configuration. A total of six relays may be available with the thermostat and sub-base. The auxiliary relay may be configured for an economizer, time of the day (TOD), dehumidification, or an additional stage of heating or cooling. The selections that may be disabled are the network input options, the relative humidity sensor and the occupancy sensor. Table 21 shows an installer configuration option for sub-base 2.

Table 21

Installer Configuration Option	Sub-base 2
Heating output stages	2
Cooling Output stages	2
Room humidity sensor	0

Sub-base 3 may be a three heat stage/three cool stage configuration. This sub-base may allow for conventional or heat pump operation. A total of 8 relays may be available with the thermostat and sub-base. The auxiliary relay may be configured for an economizer, the time of the day, or dehumidification.

33

This sub-base may be configured for a two heat stage/ four cool
stage configuration by using the third stage of heat for an
additional stage of cooling. The selections that may be
disabled are the network input options. Table 22 shows an
5   installer configuration option for sub-base 3.

Table 22

Installer Configuration Option	Sub-base 3
Heating output stages	3
Cooling Output stages	3
Room humidity sensor	1

Sub-base 4 may be a modulating configuration. Relative to
the modulating sub-base configuration screen context rules, a
10   total of 4 relays may be available with the thermostat and sub-
base. The auxiliary relay may be configured for an economizer,
time of the day, dehumidification or an additional stage of
heating or cooling. The cooling and heating action (direct and
reverse) may be shown. Table 23 shows an example installer
15   configuration option for the various sub-bases.

Table 23

Installer Configuration Option	Sub-base 1	Sub-base 2	Sub-base 3	Sub-base 4
Heating output stages	1	2	3	0
Cooling Output stages	1	2	3	0

34

PDA configuration tool 12 may arrange and store user

preferences. A preference selection for units may include SI

(C) and US conventional (F). There may be a preference for

alert messages such as an enable/disable alert warning regarding

5   unsupported PDA OS™ versions. User preferences may be stored in

a dedicated file. There may be one user preference set per PDA

platform.

Preferences for regional design parameters may be stored in

a default thermostat configuration. New configuration files may

10   be instantiated with the default thermostat configuration. The

user may modify the default thermostat configuration. One may

lock configuration default files. The user preferences may

support functions for locking and unlocking the default

configuration files including the general thermostat

15   configuration, the weekly schedule and the holiday schedule.

The configuration tool database manager may support 250

named configuration files in a space of 500K bytes of PDA

memory. The tool application software may use up to 500K bytes

of PDA memory.

20   The following figures effectively show what may be

displayed on a PDA when configuring or doing settings. Figure

3a may be the opening screen of configuration tool 12 of

programmable thermostat 11. One may configure offline by

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selecting a new configuration. Then, in the next screen,
illustrated in Figure 3b, one may enter a description of the new
configuration under "Description".

One may connect and configure with an existing arrangement

5   on the PDA. Various versions of firmware and software in
thermostat 11 may support the processes in the following
figures. Figure 4a is an opening screen where one may click
"Select Existing Config". The next screen in Figure 4b shows
existing configurations on which one may click "Example2", which

10   may result in the next screen as illustrated in Figure 4c.
Here, one may click "Downld", which may bring a screen as shown
in Figure 4d. Then one may click "OK" to connect the PDA serial
port to the T7350 thermostat. On the other hand, one may
configure a new arrangement and then connect in Figures 5a, 5b

15   and 5c. One may click a "New Config" on the opening screen of
Figure 5a and enter the new configuration name and its
description on the next screen in Figure 5b. The thermostat may
be configured clicking the "Next" button to navigate it for
entering the new configuration selections, features and

20   settings. Clicking the "DownLd" button may result in the screen
of Figure 5c for the opportunity of serially connecting the PDA
12 port to thermostat 11.

Figures 6a through 6c relate to connecting and modifying the existing configuration. On the opening screen of Figure 6a, one may click "Upload Config" and get the connecting screen in Figure 6b where one may connect the PDA to the thermostat by

5   clicking "OK". In Figure 6c, customer XYZ configuration may be loaded. Using the "Next" button, one may navigate and modify the loaded configuration. After modification of the configuration, one may click the "DownLd" button of screen in Figure 6c to get the box for connecting PDA 12 to the thermostat

10 11 for downloading the modified configuration. Figure 6d shows a dialog box for connecting PDA 12 to the thermostat 11.

Figures 7a and 7b show screens that may be used for connecting and calibrating the thermostat. Figures 8a, 8b and 8c illustrate the sequence for connecting, reading and saving,

15 that is one may click "Upload Config" on the opening screen and connect in the box that comes up and when ready to save, click the "Save" button in the screen of Figure 8c. Figures 8d and 8e relate to monitoring data.

Figures 9a through 9j illustrate novice configuration and

20 navigation. One, i.e., the user, may click on the "Next" button of the screen of the selected existing configuration, viz., Example3, in Figure 9a to navigate it. Figure 9b shows a selection of sources of inputs for room temperature, room

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relative humidity, discharge air temperature and outdoor

temperature. After clicking the selections, the user may click

"Next" and go to another screen for an output selection of

"AuxDO" of the time of the day, economizer or the dehumid hot

5   gas BP shown in Figure 9c. A next screen may be the cooling

configuration in Figure 9d for a selection of the number of

stages, cooling response, lockout, and set point degrees F.

Figure 9e shows a similar screen for heating configuration with

a selection for stages, auxiliary stages, heating response, lock

10   out and OAT. Figure 9f is a screen that relates to features of

the fan such as the switch of "On" or "Auto", operation of

conventional or electric heat, extended operation or not for

heat and cool. An events schedule screen in Figure 9g provides

for the modification of the schedule relative to unoccupied and

15   occupied times of each day of the week. To insert changes, the

user may click on "Modify", which may bring up the screen shown

in Figure 9h, where the user may enter the times of occupancy

for the various days of the week. Figure 9i shows the screen

where one may enter the temperature set points for heating and

20   cooling for the events of a space that is occupied, unoccupied

and the standby mode. Also, a temperature override interval in

terms of hours may be entered. The "Summary" screen of Figure

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9j may be returned to upon which the user may save the changes

to the configuration.

Figures 10a through 10m reveal a sequence for an advanced

user configuration. Figure 10a is a summary screen of the

5   selected configuration. The user may click the "Summary" tab or

menu and one gets the menu across the top of the screen as shown

in Figure 10b. "Set" may be clicked for a menu of items that

may be set. "Sched" may be clicked as in Figure 10c for a menu

of scheduling items. One may click "Display" under "Set" in

10   Figure 10b and get the screen of Figure 10d where certain

display options can be selected. Clicking on dehumidification

in Figure 10b, one may get the screen of Figure 10e where one

may select dehumidification options. Clicking on "EnergyMgmt"

under "Set" may result in several choices in Figure 10f, such as

15   the demand limit control bump and the power failure sequence

start. Loop tuning under set may bring forth a screen in Figure

10g where one may select appropriate set points. "Recovery" may

be selected under "Sched" on the screen of Figure 10c where one

may select temperatures for starting cooling and heating based

20   on outside air temperatures and ramping up and down rates, as in

Figure 10h. The daylight saving time selected under schedule

may result in the screen as shown in Figure 10i where the start

and stop of daylight saving is to start and stop for the year.

The "Holiday" selection under schedule may result in the list of

holidays in Figure 10j or 10l of which one may want to click on

"Modify" to get the screen in Figure 10k and thereby select the

start time and duration of the selected holiday. The user may

5   click on "Opt" in Figure 10c and then click on "User Pref".

Then one may select units, the OS alert message and the lock of

defaults as shown in Figures 11a and 11b.

Figures 12a through 12c show file commands. One may click

on "Summary" to get the menu which includes "File". A click may

10   be applied to "New", "Open", "Save", "Save As", "Beam" or

"Delete" relative to a configuration. Figures 12b, 12c, 12d and

12 e show the resulting screens, respectively, to start a new

configuration, open a current configuration, save a

configuration as and delete a configuration.

15   The time clock may be set with configuration tool 12.

However, the configuration tool should be connected to

thermostat 11 so that the thermostat real time clock may be set.

The calendar year, month and day may also be set. These

settings may be effected by using the PDA 12 time or it may be

20   entered manually. Figure 13 shows the screen for the set clock

mode.

Figure 14a shows a start-up screen for a tool on a Palm™

PDA 12. The main screen appears in Figure 14b and one may

upload a program from thermostat 11. Then "set up" may be

selected in Figure 14c and get to a program in Figure 14d. One

may select a day such as Sunday to schedule. Figure 14e shows a

schedule of Sunday and the occupied time may be selected, as in

5   Figure 14f. One may select the even time or time period for

that occupied time in the screen of Figure 14g and do the set

points in the screen of Figure 14h. One may also do the

installer set up, for example, relative to the display in Figure

14i. Setup 2 may include selecting the heat and cool stages,

10   for energization selection and sensor location, as shown in

Figure 14j. Then one may load the program for a particular

file, to be for the HVAC system for a particular location, such

as a merchant, like "Standard 1", as indicated in Figure 14k.

The configuration for Standard 1 may be downloaded to the

15   respective thermostat 11, as in Figure 14l. This configuration

may also be saved under a file name in Figure 14m.

Figures 14n, 14o and 14p show screens about the enabling of

partial downloads after the opening screen. Partial downloads

may include weekly schedule, holiday and set points. Figure 14q

20   has "Home" added to the Set menu for returning to the opening

screen in Figure 14r. The user may be asked to save the current

configuration before moving on.

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PDA tool 12 may support thermostat field commissioning

tasks including a temporary checkout mode (such as eliminating

time delays) as well as a manual output mode. Figures 14s-14z

are screens supporting an override option scenario. The screen

5   of Figure 14s or 14t may provide the menu or home screen,

respectively, for selecting an override option. Figure 14u

shows the connection message. Figures 14v and 14w reveal

override screens for "Mod SubBase" and "3H3C SubBase",

respectively. In the override screen of Figure 14x, the user

10   may tap the manual button. Tapping the screen of Figure 14y may

let the user exit the manual mode. The screen of Figure 14z may

warn the user if there is an exit with delays off or disabled.

Configuration tool 12 may be connected to thermostat 11 to

read an online status report. The status report may include

15   data, but not limited to, such as the thermostat firmware

version, thermostat hardware version, sub-base hardware version,

run time error messages, space temperature, remote temperature

set point input, discharge air temperature, outside air

temperature, number of heating stages active, heating capacity

20   output in percent, number of cooling stages active, cooling

capacity in terms of percent, remote space relative humidity in

percent, occupancy status (on or off), effective fan setting

(on, off or auto), fan status (on or off), mode (heating or

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cooling), economizer logic state (on or off), occupancy override

status, and run time data. The configuration arrangement and/or

the online status report may be transferred (HotSync) to, for

instance, a Palm™ or desktop PC application or to another PDA

5   12, via light beam technology or other ways. Thermostat

configuration summaries may be saved to a Palm TM memo, which

may also be similarly transferred. There may be a password or

other security approach to prevent other PDA users from changing

the default files established by the local control manager.

10   PDA 12 may be connected to thermostat 11 to make limited

changes, such as one or several configuration parameters,

holiday schedules, weekly schedules, operating mode, temperature

settings, and so forth. The PDA 12 tool may support thermostat

field commissioning tasks including a check-out mode

15   (eliminating time delays during check-out). The check-out mode

may be automatic or manual. Table 24 shows a configuration

option with related information.

Table 24

Config Option	Default	Min	Max	Res	Units	Description
DisableDelays	0	0	1	1		0: Not in system Checkout Mode 1: In System Checkout Mode (disable delays on relays, sequential start, ...etc)
ManualMode	0	0	2	1		There may be a couple of bits for mode: 0=Run, 1=manual, 2=Factorytest.
ManualMode	0	0	2	1		Each relay/AO labeled on the Palm like it is on the Stat. So the Palm would determine if it is a Heat pump or conventional and then display the labels.

20

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ManualMode	0	0	2	1		Will provide a Manual Mode to turn on/off each output. The user enters and exits manual mode using the PalmTM OS Configuration Tool. The T7350 automatically terminates manual mode if periodic updates are not received or the user disconnects the serial cable from the PalmTM OS Configuration Tool.
ManualMode	0	0	2	1		Manual Mode is not a flashed "permanent" state. Manual mode or test-speedup mode is not remembered through a power down or restart.
Relay1	0	0	1	1		There will be 8 bits (1byte) for the 8 relays. 0=off 1=On
Relay2	0	0	1	1		
Relay3	0	0	1	1		
Relay4	0	0	1	1		
Relay5	0	0	1	1		
Relay6	0	0	1	1		
Relay7	0	0	1	1		
ModOut1	0	0	100	1	%	There will be 2 bytes for the modulating outputs: 0-100% each. When thermostat sees mode change to manual, it may set the outputs to the values specified.
ModOut2	0	0	100	1	%	

One may monitor thermostat operating data to determine the health of the thermostat. Tables 25 and 26 indicate the various configuration items and parameters that may be monitored. Table 25 shows the input data that may be monitored.

Table 25

Min	Max	Res	Units	Description
				Space Temperature
				Remote temperature setpoint input
				DAT
				OAT
				Space RH %
				Occupancy sensor status (on/off)
				Fan status (on/off)
				Occupancy override status

Table 26 shows the items and output data that may be monitored. Operating modes may likewise be monitored.

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Table 26

Min	Max	Res	Units	Description
				# of heating stages active
				Heating capacity output %
				# of cooling stages active
				Cooling capacity output %
				Economizer logic state (on/off)

Table 27 lists some models and their data that may be
monitored.

5

Table 27

Min	Max	Res	Units	Description
				Dehumidification: Reheat
				Dehumidification: SetPoint Reset
				Dehumidification: Min On Time Extended
				Recovery Mode
				Operational Mode: Heating /Cooling

				Effective SetPoint
				DLC
				Real Time
				Operating Date
				Heating Lockout Mode
				Cooling Lockout Mode

Thermostat operating data may be monitored. A table 28 may
provide data values with display dependency rules.

10

Table 28

Display Key: A - Always display
             D - Display based on context Dependency
             N - Never displayed
15   V - Verbose mode only

Thermostat Data	Display	Display Dependency	Report Text Description	Comments
version.major version.minor version.bug	A		FirmwareVersion:0.0.19	
version.commVer	V		ComVersion: 1	
version.rePgmrVer	V		ReProgrammerVersion:	
status3.subBaseType	A		SubBaseID: T7350D,3H3C	
subBase.connected	V		CommunicatingSubBase:Yes	
statusAnalog.spaceTemp	A		RoomTemperature: 75F	
statusAnalog.dischTemp	D	configured	DischargeAirTemp: 105F	config.dischAirSensor
statusAnalog.spaceHumidity	D	configured	Room RH: 33%	config.humiditySensor
statusAnalog.oDTemp	D	configured	OutdoorAir: 25F	config.oDAirSensor
statusAnalog.remoteStPtOffset	D	configured	RemoteSetPtOffset: 2F	config.remoteSetPoint

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Thermostat Data	Display	Display Dependency	Report Text Description	Comments
statusAnalog.temporarySetPt	D	value <> 0	TemporarySetPt: 76F	Display actual temporary setpoint if Delta value <> 0
status1.totalError	N			Total error reported by the control loop.
status1.bypassTime	D	value > 0	BypassTime: 180 min	
status1.tuncos	N			Time until next scheduled change of occupancy state:
status1.DaysLeftKeypadHoliday	D	value > 0	HolidayDaysRemaining: 7	
status1.currentState	A		TimeSchedule: OCC	Current scheduled occupancy state 0: OCC 1: UNOCC 2: BYPASS 3: STANDBY 7: OCCNUL
status1.nextState	N			
status1.occSensor	D	configured	OccSensor: 0	config.occSensor = 1
status1.holiday	N			
status2.heatStgsOn	A	configured	HeatingStagesActive: 2	
	D	configured	AuxHeatingStagesActive: 2	Control = HeatPump
status2.coolStgsOn	A	configured	CoolingStagesActive: 1	
status2.percentCmdHeat	D	configured	HeatingOutput: 57%	SubBaseID = M
status2.percentCmdCool	D	configured	CoolingOutput: 33%	SubBaseID = M
status2.outFan	N			
status2.outCool1	N			
status2.outCool2	N			
status2.outCool3	N			
status2.outAux	A			
status2.outHeat1	D	configured	O/BChangeoverOver: ON	Control = heatpump config.heatPump
status2.outHeat2	N			
status2.outHeat3	N			
status2.effMode	A		EffectiveMode: Cool	Effective operating mode: 0: OFF_MODE 1: COOL_MODE 2: HEAT_MODE 3: EMERG_HEAT_MODE 4: REHEAT 5: MANUAL 6: FACTORY_TEST
status2.fan	A		FanStatus: ON	
status2.auxRelay	D	configured	Economizer: ON	NotHeatPmp AND Subbase > 1 config.auxOpMode = 1
	D	configured	HotGasDehumidification: ON	config.auxOpMode = 2
	D	configured	SimpleDehumidification: ON	config.auxOpMode = 3
	D	configured	TimeOfDayContact: ON	config.auxOpMode = 0
status2.unused1	N			
status2.stagesActive	N	configured		
status2.noAuxHeat1	N			
status2.noAuxHeat2	N			
status2.dehumidActive	N	configured	Dehumidification: ON	RH sensor configured
status2.DALimit	D	configured	DishargeAirLimiting: ON	config.enableDALoLimit = 1 OR config.enableDAHiLimit = 1
status2.unused2	N			
status3.effOccTuncos	N			
status3.effSetPt_s6	A		EffectiveSetPoint: 72 F	
status3.effOccCurrentState	A		EffectiveOccupancy: OCC	
status3.unused1	N			
status3.effOccNextState	N			
status3.unused2	N			

Thermostat Data	Display	Display Dependency	Report Text Description	Comments
status4.terminalLoad	V			

One may backup thermostat configuration files from PDA 12 to a PC. These PDA configuration files may be restored in the event of battery failure or PDA demise or loss. If the latter

5   occurs, one may go to a store and purchase another PDA and upload the files from the PC, and continue about the business with the new PDA.

A PC archive of thermostat configuration information may have several benefits. The PC archive database may support

10   multiple PDA users. Individual thermostat configuration files may be organized in groups by customer building or project name. PDA users may from such database select individual configurations and incrementally install them on a specific PDA using the PC hot sync function. The function may be hardwired

15   or be an IR or other wireless method. Other connective functions may be implemented. There may be last session information. In other words, the PDA or PC user may be returned to the last edited configuration file and last used configuration screen. Also, a list of the last five or so

20   configuration files opened by the user may be presented upon going into the configuration program. There may also be various warnings about the adequacy of the PDA hardware and software.

47

The PDA user may be able to field calibrate analog outputs. For high accuracy on the analog outputs or inputs, the user may modify gain and offset constraints. For instance, the user may field calibrate the humidity sensor. The user may be able to

5   add an offset to the sensor reading. Various abbreviated titles, terms and acronyms may be connected by PDA 12 with a button toggle to obtain the full title or meaning. For instance, one may toggle on "LeadTimeInfo" to get "Lead Time Table of Information."

10   PDA 12 may not only upload a configuration from thermostat 11, but it may be able to upload a contractor's name, logo and telephone number. This information may be presented on the screen of PDA 12. Also, it may likewise be displayable on thermostat 11. Such information may be useful in case there is

15   a thermostat problem, regular preventive maintenance or routine check scheduled, filter change needed, a seasonal configuration change, or other items in which contacting a contractor could be helpful.

Figure 15 is a flow diagram of an entry of a contractor's

20   phone number and logo graphic (and possibly additional information) on a PC at block 16. The format of the logo graphic may be checked at junction 17. If the format is not proper, then it may be converted at block 18. If or when the

48

format is proper, then it may be checked for size at junction

19.   If the logo is not the correct size, then it is not resized

at block 20.   If and when the logo is of acceptable size, then

the contractor information may be stored in the PC.   At block

5   21, the contractor information may be transferred as data from

the PC to a PDA or portable memory media (e.g., smart media,

compact flash or a memory stick).   At block or step 22, the

contractor information data may be transferred to thermostat 11

EEPROM/FLASH 23 via PDA 12 using an easy wire, IR or RF

10   connection, or via a portable memory.

The electronic thermostat assembly may consist of two

pieces, the cover assembly 30 and sub-base 14.   The cover

assembly may include, but is not limited to, the MMI and a

display 38 for 7-day programming.   Assembly 30 and display 38

15   are shown in Figures 17b and 17a, respectively.   The sub-base(s)

include the equipment control connections.   The sub-base is

mounted on the wall and the thermostat cover assembly is mounted

on the sub-base.   Different sub-bases will be used for different

applications including; up to 3 heating stages/3 cooling stages

20   or 2 heating stages/4 cooling stages, modulating outputs, and

dehumidification high limit control.   Each sub-base is

compatible with the common cover assembly.

There may be a disable delay/sequential start option. This
may allow faster testing in the field by disabling the minimum
on/off time delays for relay outputs and the sequential start
delay. The rate at which the control algorithm runs (once every
5   10 seconds) determines the rate at which stages cycle on and
off. Other test options may include the following.

The installer may enter the disable delay option by
pressing a special combination of keys and selecting "in-test"
and then pressing the "run" key. The installer may exit the
10   disable delay option by pressing a special combination of keys
and selecting "no-test" and then pressing the run key.

There may be a capability to field flash thermostat 11 from
the serial port. This may allow the user to upgrade the
firmware in the field. Initially, a lap-top PC 24, running a
15   special program may be used to connect to the thermostat serial
port. Later, a program may be developed to do this through the
Palm™ OS configuration tool. Schedule programming, installer
configuration options, set points, system switch, fan switch,
and keypad lockout may all be field adjustable through the
20   thermostat keypad/LCD or a Palm™ OS configuration tool. Some
parameters may be configured and monitored only through the
Palm™ OS configuration tool. Others can be configured and

monitored from both the keypad/LCD and Palm™ OS configuration

tool 12.

Figure 16 is a thermostat system level diagram with major

components and a system communications overview. Thermostat 11

5   may interface with remote air management system or HVAC

equipment controls 26, external sensors and switches 25, and a

remote wall module 27. Signals, including commands to

equipment, between thermostat 11 and air management or HVAC

controls 26 may be via connection 33. External sensors and

10   switches 25 may include discharge air temperature, outdoor air

temperature, humidity and occupancy sensor. Information from

sensors and switches 25 may be conveyed along connection 29 to

thermostat 11. Remote wall module 27 may include a temperature

sensor, an override switch with an LED and a warmer/cooler (set

15   point offset) knob, with related information being conveyed

between module 27 and thermostat 11 along connection 31.

Thermostat 11 may have a serial communications set-up or

interface module 28 to allow inboard and outboard information to

go between thermostat 11 and set-up 28 along a connection 32.

20   Communications between set-up or module 28 and an external

device 56, such as an installer configuration tool 12 and a

communicating sub-base 14, may be via a connection 34. Firmware

to thermostat 11 may be downloaded form an appropriate device 36 via a JTAG interface connection 37.

Thermostat 11 may be configured using an "Installer Setup" through the thermostat keys on cover assembly 30 for basic setup

5 functions. More advanced features may be available through installer configuration tool 12. Installer configuration tool 12 may be compatible with a Palm™ OS handheld computer.

There may be a thermostat 11 output modulation control. This approach may solve problems associated with control issues

10 by sending analog heating and cooling signals to be implemented by controls of an air management system or roof top unit 40 of Figure 21. System or unit 40 may have a duct 39 for taking in outside air (OA), a duct 41 for taking in return air (RA) of a space, and a duct 42 for discharging air (DA). Unit 40 includes

15 a cooling unit 43 and a heating unit 44. Several enhancements and options may exist in the algorithm and thermostat configuration to assist and lead to control of water valves and oversized heating coils and loads. There may be various approaches for implementing analog output and modulation in a

20 thermostat. One may use configuration codes in the sub-base combined with a configuration tool and interchangeable sub-bases.

The present electronic thermostat system may consist of two components, thermostat 11 and the sub-base 14. The thermostat may include a human interface and display for user programming, the microprocessor, four relays, a space sensor and a power

5   supply. The sub-base may include equipment control connections, additional relays, optional analog output, and some power supply components. The sub-base may be mounted on the wall and the thermostat may be mounted on the sub-base. Different sub-base types may be used for different applications including up to

10   three heat/three cool or two heat/four cool, modulating outputs, dehumidification high limit control, and communications with a building automation system. All sub-base types may be compatible with the thermostat.

A Palm™ PDA may be connected to the thermostat and be used

15   to configure or program the thermostat. The communications port may be used by the factory to test the hardware features of the device. An optional remote wall module may be attached to the device to sense space temperature, control the set point, initiate a schedule override timer, and display the status of

20   the override timer.

Thermostat 11 of Figure 1 may contain a software component in the thermostat that allows automatic configuration of the output actuation type (modulation and discrete) identified by

53

the sub-base with preset configuration resistors. Additional

configuration information may be provided in the Palm™

configuration tool that allows setting of the parameters related

to the modulating outputs. The following table reveals the

5   various options for the sub-bases.

Table 29

Installer Configuration Option	Sub-base 1	Sub-base 2	Sub-base 3	Sub-base 4
Heating output stages	1	2	3	0
Cooling Output stages	1	2	3	0
Heating Throttling Range ®	3	4	7	5
Cooling Throttling Range ®	3	4	7	5

The next table relates to modulating system valve control.

Table 30

Cooling Valve	Applies to the modulating Cooling valve 0=direct acting. 1=reverse acting.
Heating Valve	Applies to the modulating Heating valve 0=direct acting. 1=reverse acting.

10

The hardware component of the output actuation may be

implemented though an analog output set. The microprocessor may

output the signal as a duty cycle signal that is driven into a

digital to analog conversion circuit.

15   This system may solve the problems associated with control

issues by implementing a true analog heating and cooling signal

to be implemented by the roof top 40 control system. Several

enhancements and options exist in the algorithm and thermostat

configuration to assist and lead to control of water valve

54

control and oversized heating coils and loads. Under staging

conditions, traditional control algorithm techniques may be used

to control the on/off control to the heating coils, cooling

coils and fan. When used in a modulating configuration, special

5   analog driver circuits may allow the output from the thermostat

to provide 4 to 20 milliamps and 2 to 10 volts for direct

interfacing for the control of modulated components. These

control parameters are popular ranges for many modulated dampers

and valves used in air management systems, such as HVACs.

10   The thermostat may contain a software component that allows

automatic configuration of the output actuation type (modulation

and discrete) identified by the sub-base with preset

configuration resistors. The hardware component of the output

actuation may be implemented through an analog interface set

15   from the thermostat. Analog control and interface to the

modulation may be controlled through software algorithm PID and

staging information. If additional heating is desired after a

stage is added at low load, additional supply is available

through increasing of the analog heating signal. Applications

20   of this modulating thermostat may be used for boiler firing rate

controls and other energy supply or cooling type equipment.

Through the use of programmable memory, additional algorithms

can be developed to apply to a wide range and variety of control

applications besides air management system control.

The present thermostat may provide modulated/analog control

of an air management system and discrete/digital control of the

5   same or another air management system. This thermostat may

provide modulating control of a single stage of heating and/or

cooling. On the other hand, this thermostat may provide

modulating control of multiple stages of heating and cooling.

Using a modulating signal to control each cooling or heating

10   stage may result in maintaining the outputs of the controlled

stages at efficient levels. If more output is needed from that

stage, the thermostat may, with a modulating output, call on

another stage and control it for more heating or cooling, so as

to maintain the better efficiency of the first stage by not

15   increasing the modulating output to the first stage to increase

its output. Also, modulated control may result in the next

stage's approaching an efficient level of output. This approach

may continue for more or less output as needed from the

respective stages. The thermostat may provide analog or digital

20   signals for controlling single or multiple cooling or heating

stages. The thermostat may have any combination or all of these

features.

Figure 17 is a block diagram of a modulating commercial

thermostat system. The system is composed of several major

components including a Honeywell™ T7350 thermostat 11, a

configuration tool (PDA) 12, and external mechanical equipment

5   57. Thermostat 11 may be composed of several major sections

including a cover assembly 30, modulating sub-base 14 and

external sensors. External sensors may include discharge air

sensors 64, outside air sensors 65, a humidity sensor 66, and a

space temperature sensor 67. These sensors may be connected to

10   an analog-to-digital converter (ADC) 59. Within a cover

assembly 30, a microprocessor 61 may contain the software

instructions that control the interface between the control

algorithm and the ADC and digital input/output (I/O) blocks 59

and 58, respectively. Microprocessor 61 may be a

15   microcontroller having a schedule and an algorithm, and a flash

memory. A JTAG connection 37 to microprocessor 61 may allow

upgradeable field programming and real time emulation of

operation. A real-time clock 62 may be connected to processor

61. Sub-base 14 configuration resistor 63 may be read on power-

20   up and provide an indication of a unique resistor value that

indicates the presence of a modulating sub-base.

ADC block 59 may convert the incoming analog resistance

values into digital values that can be read by microprocessor

57

61. The analog resistors values to ADC 59 may come from

discharge air sensors 64, outside air sensors 65, humidity

sensor 66, space temperature sensor 67, motion sensor 68, and

other sensors 69. Another analog input to ADC 59 may be from

5   sub-base configuration resistor 63. A modulation signal may be

derived from a pulse width modulated (PWM) signal conversion

circuit which converts the time-multiplexed duty cycled signal

from the algorithm of processor 61 into a 4-20 milliampere (mA)

modulating signal. The 4-20 mA signals may be fed, via the

10   modulating cooling interface 72 and modulating heating interface

73, to HVAC mechanical equipment 57 and may be used to control

space temperature with analog control dampers among other HVAC

mechanical equipment 57, as needed. A digital I/O 58 may be

connected to microprocessor 61. A motion sensor 68 and other

15   external sensors 69 may provide signals to processor 61 via

digital I/O 58. Processor 61 may provide signals to cooling

relay 74, heating relay 75, fan relay 76 and auxiliary relay 77.

The outputs of these relays may be connected to HVAC mechanical

equipment 57.

20   Since modulating control of both heating and cooling valves

may be under microprocessor 61 control via modulating cooling

and heating interfaces 72 and 73, respectively, and since

thermostat 11 may be capable of humidity control, the thermostat

58

can in general control or limit humidity effectively through the

use of modulating the cooling as necessary to reduce the

humidity of the outside air that typically accounts for most of

the humidity load in a commercial building. Different

5   strategies may be used to do dehumidification control including

the use of both heating and cooling relays and heating and

cooling modulating valves in different ratios. Modulation of

dampers to control the volume of air per unit of time through

the cooling mechanism may also be used for dehumidification

10   control.

Figure 18 is a block diagram of the networked modulating

thermostat. Components associated with thermostat 11 may

include the system sequencing control 78, which may be a

Lonworks™ communicating node that allows network information to

15   be shared on a network communications bus 84 in the form of

"network variables". Standard network variables may exist for

standard representations of temperature, humidity, and digital

on/off and analog values. Sequencer 78 may have a local sensors

79 connection. The availability of modulating controls may

20   allow for a master sequencing control 78 node to make staging

and modulating decisions for the whole system based on local

sensors. Also, local sensor information may be shared on a one-

to-one, or one-to-many basis using a Lonworks™ process called

"binding". It may allow, for instance, the outside air

temperature and outside humidity signals to be shared across

multiple controllers, including information for temperature and

humidity control for individual nodes 82 and 83. Controller 192

5   may be associated with node 82. Controller 192 may have a

thermostat 11 and a sub-base 14 which are set up for two stage

cooling and two stage heating. Mechanical equipment 57 may be

driven with digital-like, discrete, non-modulated signals from

controller 192. Sources 194, 195 and 196 connected to

10   thermostat 11 may provide temperature, humidity and outside

parameter information, respectively, to controller 192. Other

controllers on bus 84 may likewise have such sources connected

to them. Also, a controller 193 may be associated with node 83.

Controller 193 may have a thermostat 11 and a sub-base 14 which

15   are set up for modulated one stage cooling and heating.

Mechanical equipment 57 may be driven with analog, modulated

signals from controller 193. Thermostat 11 of controllers 192

and 193 may be the same thermostat or different thermostats. If

these controllers have the same thermostat, that thermostat may

20   have the capability of controlling both non-modulated air

management systems and modulated air management systems.

    In Figure 18, there may be numerous other nodes having

additional controllers (though not explicitly shown) associated

60

with them, respectively. The controllers may output non-modulated or modulated control signals to their respective mechanical equipment which may consist of HVACs, respectively, having valves and/or dampers controlled by signal outputs from

5   their corresponding controllers. Often, the air management systems, such as HVACs, that are recipients of the non-modulated control signals, are multiple stage cooling and heating systems. And often, the air management systems, such as HVACs, that are recipients of the modulated control signals, are single unit

10   cooling and heating systems. However, in lieu of the latter single unit systems, there may be modulated multiple stage cooling and heating systems. Both modulated and non-modulated systems may also have humidity control.

Sequencing information may be collected from sensors 79 on

15   node 81 or network binding sensors to allow for sequential staging and algorithm enhancements. Local and non-local sensors may be those for measuring temperature and humidity, and other parameters. The sensors may be situated in various locations such as outside, the controlled space and in or proximate to the

20   air management equipment. Since the individual nodes may command analog and digital values from both the local node and the system node, the system node can command individual node analog and digital values as required in temperature (and

61

sometimes humidity and other parameter) control systems, such as

HVACs.

System sequence control 78 may be a controller configured

as a sequencer with controllers 192, 193 and others added and

5   connected to the network communications bus 84. Controllers

192, 193 and the like may act as individual controllers which

periodically send status messages to sequencer 78. Also,

sequencer 78 may periodically send information, instructions and

commands to controllers 192, 193 and other like controllers, if

10   any. Such information, instructions or commands may affect the

respective controller's control of mechanical equipment 57 of an

HVAC or other air management equipment.

Sequencer 78 may also control a multi-stage heating and

cooling system via thermostat(s). That is, there may be

15   modulated control of each stage of heating and cooling. The

percentage a stage's maximum output may be somewhat less than

100 percent. That percentage may be determined, for example, by

an effective operating efficiency singlely or in combination

with one or more other stages. Other bases may be used for

20   determined the percentage of maximum operation of a stage. The

percentages may be different among the stages and dependent upon

parameters such as temperatures, humidity and so forth.

Sequence control may also be of non-modulated stages or of a mix

of modulated and non-modulated stages. The sequence may be
utilized for air management systems having humidity control. A
user interface 197, similar to interface 30, having a keyboard
and a display, may be connected to sequencer 78 for programming,

5   configuring and testing the sequencer and associated controllers
on communications bus 84. A personal digital assistant (e.g.,
PDA 12) may be connected to user interface 197 or directly to
sequencer 78 for programming, configuring and testing the
sequencer and associated controllers on communications bus 84.

10   The connection of the PDA to interface 197 or sequencer 78 may
be via a wire or wireless medium (e.g., RF, infrared or optical
fiber). Each thermostat 11 associated with bus 84 may likewise
have a user interface 30 and PDA 12 as disclosed herein.

Figure 19 is a flow diagram of the modulating sub-base

15   sequence. An input may enter the sequence at decision 85 which
asks whether the power is within acceptable limits. If not, a
power shut-down may be initiated along with the saving of the
schedule and configuration, as indicated in block 86. If the
power is within acceptable limits, then the analog/digital (A/D)

20   registers may be initialized and the analog outputs commanded to
4 mA, according to block 87. The output of block 87 may go to
block 88 and cause the sub-base configuration resistor ID to be
read. The next question of symbol 89 may be whether the

63

modulating resistor identification (ID) is valid or not. If

not, a signal may be sent back to the beginning of block 88 and

the process may repeat itself with the same question of

validation of the modulating resistor ID. If the resistor ID is

5   valid, then a signal may be sent from decision diamond 89 to

block 91 for the temperature and humidity sensors to be read.

After these readings, control algorithm action of block 92 may

occur. The measured value temperature minus a temperature set

point may equal the error, and the humidity error may be a

10   function of humidity value and the humidity high limit. After

the action of block 92, an output may go to symbol 93 to ask

whether an analog modulating sub-base is present. If not, then

a digital output may be a function of measured temperature

error, measured humidity error, and configuration type, as in

15   block 94. If so, then a modulating output may be a function of

measured temperature error, measured humidity error and

configuration type, as in block 95.

Figures 20a and 20b show an illustrative example of a

display 38 and a keypad 45 user interface 30. Keypad 45 may

20   control HVAC equipment often described as a conventional roof

top unit (RTU) 40 with gas or electric heat and direct expansion

(DX) cooling. There may be 0-3 stages of heat, and up to 6

stages of heating and cooling combined. There may be 0-4 stages

64

of compressor, and up to 6 stages of heating and cooling

combined. There may be a single speed fan. An auxiliary relay

may be used to enable economizer dampers, TOD or

dehumidification. A heat pump roof top unit 40 may have gas or

5   electric auxiliary heat. There may be 0-2 stages of auxiliary

heat, 0-3 stages of compressor, a heating or cooling changeover

valve, and be configurable for ON for heat or ON for cool. It

may have a single speed fan. Also, an auxiliary relay may be

used to enable economizer dampers, TOD (time of day) or

10   dehumidification.

A modulating roof top unit may have a hot water valve or

modulating gas heat and/or chilled water valve. Figure 21 shows

a typical roof top unit 40. Roof top unit may have cooling

equipment 43 and heating equipment 44. It may also have a fan

15   46, a DAT 47 and an OAT 48. There may be dampers 49 and 51 to

regulate the flow of the outside air and return air to RTU 40.

Dampers 49 and 51 may have a common mechanical connection 52

which coordinates their movements relative to each other. A

control panel 50 for RTU 40 may be connected to cooling

20   equipment 43, heating equipment 44, fan 46, dampers 49 and 51,

and a heat pump cutout valve 53. Control panel may receive

control signals from and send signals to thermostat 11. A DAT

sensor 47, an OAT sensor 48, an occupancy sensor 54 and a remote sensor 55 may be connected to thermostat 11.

RTU 40 may have a heat enable, cool enable, or 0-2 stages of heat or compressor. The modulating outputs may be always active. They may be always being driven 0-100 percent. When the number of stages is zero, the relay outputs may be used to enable heating or cooling outputs. This means the relay may turn on when the modulating output is nonzero and turn off when the output is zero. Staged action may be used in addition to the modulating outputs. The number of stages may be set to 1 or 2, or more if desired. In this particular case, the relay output(s) may be used for up to 2 stages of heating or cooling. Note that the user might not have both two stages of cooling and two stages of heating. In another example, the user may have modulated heat, a heat pump enable relay and one stage of cooling. Or the user may have modulated heat, a heat pump enable relay, and two stages of cooling. The cooling analog output may be direct or reverse acting. The heating analog output may be direct or reverse acting. The may be a single speed fan. Although a multiple speed fan may be used. There may an auxiliary relay used to enable economizer dampers, TOD or dehumidification.

The hardware of thermostat 11 may have the following

configuration, which includes an internal room temperature

sensor, an LCD display 38 with back-lighting, a keypad 45, a

system and fan switching capability through the keypad, as

5   indicated in Figures 20a and 20b. Also, there may be a serial

communications link from thermostat 11 to configuration tool 12

(Palm™ OS) and a network communicating sub-base. There may be

four onboard relays with one for heat, one for cooling, one for

a fan, and one auxiliary relay.

10   Recognition of the sub-base I/O (input/output) may be

through the hardware. The thermostat cover assembly may

indicate the sub-base I/O configuration by a resistor located on

the sub-base. Each I/O configuration may have a unique resistor

value. One sub-base configuration may have modulating outputs.

15   A total of four relays may be available with a thermostat cover

assembly and the sub-base. The auxiliary relay may be

configured for an economizer, TOD, dehumidification or an

additional stage of heating or cooling. There may be a

modulating heating output and a modulating cooling output. Also

20   included may be a humidity sensor mounted in the sub-base, a

remote room sensor, a remote room humidity sensor, a remote

discharge air temperature sensor, a remote outdoor air

temperature sensor, and remote occupancy input (digital input).

67

There may be access to the serial communications port on the thermostat. The modulating sub-base may or may not support heat pumps.

An open, short, or out-of-range on the internal or remote

5 room sensor input(s) to the thermostat may cause the outputs to be turned off. The fault detection might be just done on the sensor being used. That is, if the internal sensor is being used, faults on the remote sensor are ignored. The system may provide proportional plus integral plus derivative temperature

10 control.

There may be testability capabilities. The thermostat may cooperate with factory testers such as in-circuit and functional tests to verify its functionality. The industry standard JTAG port will be available for the factory tester to program the

15 flash memory and test the device. Boundary Scan, formally known as IEEE/ANSI 1149.1_1190 is a standard which facilitates testing, device programming and debugging at the semiconductor, board and system levels. The standard came about as a result of the efforts of a Joint Test Action Group (JTAG) formed by

20 several North American and European companies. IEEE Std 1149.1 was originally developed as an on-chip test infrastructure capable of extending the lifetime of available automatic test equipment (ATE). This methodology of incorporating design-for-

test allows complete control and access to the boundary pins of

a device without the need for a bed-of-nails or other test

equipment. The OS label applied to the control represents the

features of the control. This product may be designed such that

5   100 percent of the inputs and outputs can be tested in the

factory.

One may interface to a Palm™ OS tool to do installer

configurations, set parameters, set schedules and tests,

including factory-like testing, and diagnostics. The Palm™ OS

10   configuration tool has several basic functions installer

configuration (defines the equipment attached to the

thermostat); parameter modification (gains, set points, and the

like), schedule changes, and testing and diagnostics.

Keypad 45 and LCD display 38 user interface 30 may be in

15   the flash memory file (accessed through document management

software). Thermostat 11 may have the LCD segments depicted in

Figure 20a and 20b. Figure 20a shows the available LCD elements

in display 38. There are elements for displaying time,

temperature, days of the week, humidity, occupied status, far

20   status, heat and cool status, setting for schedules and times,

and so forth. Further, display 38 may be a dot-matrix system

with shading of the respective pixels. Display 38 may be a

black and white display with a gray scale system, or a color

display which is capable of displaying graphics, pictures and

symbols, including company or contractor logos. Display 38 may

be capable of displaying video-like or television-type pictures.

Interface 30 may have a speaker for providing sound associated

5   with video information on display 38. Also, a microphone may be

attached to interface 30 for voice instructions or other audio

purposes.

Figure 20b shows user interface 30 with display 38 and

keyboard 45. Button or keys 96 and 97 may be used for entering

10   up and down settings, respectively. Key 98 may be used to

obtain information. Keypad or keyboard 45 may have a settings

group 99, set group 101, override group 102 and a program group

103 of keys. Buttons or keys 104 and 105 may be for the heat

and cool temperature set points for occupied periods. Keys 106

15   and 107 may be for heat and cool temperature set points for

unoccupied periods. The day and time of the clock may be set

with keys 108 and 109, respectively. Keys 110 and 111 of

override group 102 may be used for temporary occupied and

holiday schedule selection, respectively. Alternatively, key

20   111 may be for "Temporary Not Occupied" override, as indicated

in Table 31. One may program schedules of occupied and

unoccupied times for various days in key group 103. Key 112 may

be used to select the day to be scheduled, key 113 may be used

70

for selecting the occupied times and key 114 for selecting the

not occupied times for the selected day. Key 115 may be used to

clear the set schedule of that day. Key 116 may be used to copy

a schedule of one day into another. Other keys of interface 30,

5   include a system key 117 for selecting a cooling or heating

system, and a key 118 for putting the fan "on" or on "auto".

Key 119 may be used to run the system. Table 31 provides some

description of the various keys on keyboard 45.

Table 31

Reference Number	Grouping	Button	Definition
96	Information	Down Arrow	Used for lowering setpoints, days, and times. When setting times or temperatures, holding this key down results in continuously decreasing the time.
98	Information	➊	Used to obtain information (and setting humidity "high-limit" value)
97	Information	Up Arrow	Used for raising setpoints, days, and times. When setting times or temperatures, holding this key down results in continuously increasing the time.
104	Temperature	Occupied Heat	Set Occupied Heat setpoint
105	Temperature	Occupied Cool	Set Occupied Cool setpoint

10

Reference Number	Grouping	Button	Definition
106	Temperature	Not Occupied Heat	Set Not Occupied Heat setpoint
107	Temperature	Not Occupied Cool	Set Not Occupied Cool setpoint
108	Set	Day	Set day of week. Tapping this key when the 'Set Value' segment is on will also increase the current day (same effect as up arrow key)
109	Set	Time	Set time. Tapping this key when the "Set Value" segment is on will also increase the time in one hour increments
110	Override	Temporary Occupied	Temporary occupied setting for length of time defined by installer.

Reference Number	Grouping	Button	Definition
111	Override	Temporary Not Occupied	Set Not Occupied length. User can select length of days ("0"-"99"), or "---" for continuous override
112	Schedule	Day	Selects day schedule to modify
113	Schedule	Occupied	Selects occupied event start times for specified day. Repeatedly pressing this key toggles between two occupied events.
114	Schedule	Not Occupied	Selects not occupied event start times for specified day. Repeatedly pressing this key toggles between two not occupied events.
115	Schedule	Clear Start Time	Clears start time for specified period and day

116	Schedule	Copy	Copies schedule from one day to another.
117		System	Selects System Mode. Toggles between Em Heat, Heat, Off, Cool, and Auto modes.
118		Fan	Selects mode of fan operation. Toggles between On and Auto.
119		Run Schedule	Resumes running schedule (cancels any Temporary Occupied action, Temporary Not Occupied, or Temporary setpoint change.)

In system checkout there may be disable delay, test and monitoring from Palm™ configuration tool 11. One may be able to

5   access a manual mode from the Palm™ OS configuration tool. This may allow the user to manually turn on and off or modulate each output to verify wiring.

The electronic thermostat system may consist of two pieces, thermostat 11 and sub-base 14. Thermostat 11 may include a

10   human interface 30 and display 38 for user programming, a microprocessor 61, four relays 74, 75, 76, 77, a space sensor 67, and a power supply. Sub-base 14 may include the equipment control connections, additional relays, optional analog output, and some power supply components. Sub-base 14 is mounted on the

15   wall and thermostat 11 may be mounted on sub-base 14. Different sub-base 14 types may be used for different applications including up to three heat/three cool or two heat/four cool, modulating outputs, dehumidification high limit control, and communications with a building automation system. All sub-base

20   14 types may be compatible with thermostat 11.

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A Palm™ PDA 12 may be connected to thermostat 11 and used

to configure or program thermostat 11. Future sub-base 14 types

may have the capability of communications to a building

automation system via a net connection. The communications port

5   may be used by the factory or a PDA to test the hardware

features of the device.

An optional remote wall module may be attached to the

device to sense space temperature, control the set point,

initiate a schedule override timer, and display the status of

10   the override timer. Optional remote discharge, outdoor air,

humidity, and occupancy sensors may be attached to thermostat 11

via sub-base 14.

In the factory, thermostat 11 may be connected to a

programming device that programs the flash memory via the

15   industry standard JTAG port. This port may also by used to down

load revised software in the field.

There may be control algorithms in thermostat 11.

Thermostat 11 may be used to control the temperature and

humidity in the controlled space using heating and cooling

20   equipment. The equipment may be conventional with up to three

stages of heating and four stages of cooling, or it may be heat

pump with up to two compressor stages and two stages of

auxiliary heat. In addition economizer options and analog

control options are available with some sub-bases. The control

algorithm may be customized for various applications using

keyboard and display or an external personal digital assistant

(e.g., PDA 12).

5   In the factory test phase, the device may cooperate with

the factory tester to test the hardware inputs, outputs,

keyboard 45, display 38, and associated equipment. The hardware

of thermostat 11 may include certain significant components.

Thermostat 11 may use a Texas Instruments Inc. MSP 430 family

10   microprocessor. Processor 61 may contain on chip flash program

memory, flash information memory, RAM, microprocessor

oscillator, real time clock oscillator (external crystal),

timers for real time clock, timers for operating system and

pulse width modulation (analog output), digital IO 58 ports for

15   relays/inputs/keyboard scanning, 12 bit analog-to-digital

converter (ADC) 59 with an input multiplexer, and an LCD display

38 driver.

The microprocessor 61 port pins may be connected to:

keyboard 45 rows (inputs) and columns (outputs); an LCD display

20   38; eight analog input circuits (one on thermostat 11 and up to

seven connected via sub-base 14); one digital input for remote

wall module bypass button - connected via sub-base 14; one

digital input for occupancy sensor - connected via sub-base 14;

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transistorized relay drivers (four on thermostat 11 and up to four on sub-base 14); a low pass filter to convert pulse width modulation into analog output voltage (up to two on sub-base 14); one digital output for bypass LED on remote wall module -

5   connected via sub-base 14; one digital output to put the power supply into relay power saving mode; a serial input, output, and handshake input used to connected to the personal digital assistant 12, sub-base 14 communications system, factory tester, or tcomm (a specialty development tool); a 32,768 KHz crystal;

10   three volt power derived from a higher voltage power supply (the three volt supply may use a super-capacitor to keep the circuit alive for 48 hours or more after mains power failure); an on chip low voltage detect circuit which may be connected to the mains side of the higher voltage power supply (a detection of

15   low voltage may cause microprocessor 61 to enter a low power mode.

The context diagram of Figure 22 illustrates the various processes in thermostat 11. There may be two kinds of tasks: 1) interrupt driven; and 2) operating system driven. The interrupt

20   driven tasks may run when a hardware interrupt calls them. Interrupts do not interrupt interrupts. The operating system tasks may run periodically when an operating system 121 calls them. When no tasks are being performed, operating system 121

may run in an endless loop. The tasks may communicate with one

another through shared RAM variables. The memory in this

illustration may be regarded as RAM, unless otherwise specified.

The code may be written in the C language except that some

5   critical routines or utilities may be written in assembler.

Operating system 121 may have an outgoing hardware

connection 122 to hardware initialization. One may note a key

of symbols for figure 22. A double line block may represent a

main() system such as operating system 121. A single solid line

10   block may represent a periodic task (time), a dot-and-dash line

block may represent an interrupt task, two horizontal parallel

line symbol may represent a memory, a single line with an arrow

or arrows at at least one end may represent an internal data

path and a double line with an arrow at at least one end may

15   represent a hardware connection. There may be a two-way

internal data path connection 123 from system 121 to opSys flags

memory 124. From a low raw filter voltage detector may be an

inward hardware connection 125 and a low mains detect interrupt

task 126. Task 126 may have an internal path connection 127 to

20   opSys flags memory 124. A system clock tick interrupt task 128

may have an output to opSys flags memory 124 via internal data

path 129. A RealTimeClk and Vcc fail/recover interrupt task 131

may have an incoming hardware connection 132 from a low raw

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filter voltage detector and Vcc supervisor. Interrupt task 131

may have a two-way internal data path connection 133 with opSys

flags 124. From interrupt task 131 may be an internal data path

connection 134 to RealTimeClock memory 135, which may be

5   connected to a clock (periodic task) 136 via a two-way data path

137. Clock 136 may be connected to a central share memory 130

via a two-way data path 138. Calculate Occ and SetPoint

periodic task 254 may be connected to share memory 130 via two-

way path 267. Share memory 130 may be connected to

10   communications periodic task block 140 via a two-way path 139.

Communications task 140 may be connected to realTimeClock

135 via a two-way data path 141. Output from communications

task 140 may go to a second buffer memory 142 via a one-way data

path 143. The output from send buffer 142 may go to send

15   character interrupt task 144 via a two-way data path 145. Task

144 may have an incoming handshake hardware connection 146 so as

to indicate when character data may be transmitted out via a TX

hardware connection 147. Character information may be received

via RX hardware connection 148 to receive character interrupt

20   task 150. This information may go to a receive buffer memory

151 via a one-way data path 149. The information may then go to

communications periodic task block 140 via a one-way data path

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152. From communications task 140, the received information may

go to share memory 130 via data path 139.

ID interface periodic task 153 may receive digital inputs

via a hardware connection 154. An output from IO interface 153

5   may go to share memory 130 via a one-way data path 155. An

output from share 130 may go to map outputs periodic task block

156 via a data path 157. Map outputs task 156 may output on a

hardware connection 158 PWM outputs and relay outputs. Also, an

output from map outputs task 156 may go to a digital IO memory

10   160 via a data path 159. Such output may go to IO interface

task 153 via a two-way data path 161. IO interface 153 may

provide relay outputs and remote LED signals on an outgoing

hardware connection 162.

Input from analog sensors may go to an analog periodic task

15   block 164 via a hardware connection 163. Analog task 164 may be

connected to share memory 130 via a two-way connection 165. A

control algorithm periodic task block 166 is connected to share

memory 130 via a two-way data path 167. A schedule period task

168 is connected to share memory 130 via a two-way data path

20   connection 169. Information flash management periodic task 170

may be connected by a two-way data path 171 to share memory 130.

A configParam(info) memory 172 may be connected via a two-way

data path 173 to information flash management periodic task 170.

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A userSched(info) memory 174 may be connected via a two-way data path 175 to information flash management task 170. Defaults(code) memory 176 may be connected to information flash management task 170 via a one-way data path 177.

5 A display periodic task block 178 may be connected to share memory 130 via a data path 179. A keyScan memory 180 may be connected to display task 178 via a one-way data path 181 towards display task 178. A keyboard scanner interrupt task 182 may be connected to keyScan memory 180 via data path 183 in a

10 direction towards keyScan memory 180. Keyboard scanner 182 may be connected to keyboard 45 via a two-way hardware connection 184. Display periodic task 178 may be connected to a display memory 186 via a one-way data path towards display memory 186. The latter may be connected to liquid crystal display 38 via

15 hardware connection 187.

  Figure 23 shows further detail of the "transmit-out" portion of the system in Figure 22. Send buffer memory 142 may be connected to send character interrupt task block 188 via a one-way data path 189 towards send character task 188. Task 188

20 may send out character information via hardware connection 147. Handshake related information may be received by send character task 188 via hardware connection 146. Connection 146 also may go to handshake interrupt task 190. Handshake interrupt task

190 is connected to send buffer memory 142 via a one-way data path 191 towards send buffer 142. Data paths 189 and 191 may be represented by data path 145, and the send character task 188 and handshake interrupt task 190 may be represented by send

5   character interrupt task 144 in figure 22. Further, realTimeClock task 135 may have a broader label of "other variables" as the clock may be one of the variables.

The tables below summarize the usage of the relays for each sub-base type and the type of equipment controlled (conventional

10   or heat pump). The modulating output sub-base has two analog outputs in addition to relays. The sub-base type is detected by measuring the voltage set by resistor values on the sub-base. The following table shows the features for conventional equipment of an air management system.

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Table 32

Output (internal designation)	Sub-base1 Use As	Sub-base2 Use As	Sub-base3 Use As	Sub-baseMod Use As
Fan	Fan	Fan	Fan	Fan
Heat1	Heat 1	Heat 1	Heat 1	Heat 1
Cool1	Cool 1	Cool 1	Cool 1	Cool 1
Aux	Aux or Heat 2 or Cool2 (note 1 and 2)	Aux or Heat3 or Cool3 (note 1 and 2)	Aux or Heat3 or Cool3 (note 1 and 2)	Aux or Heat 2 or Cool2 (note 1 and 2)
Heat2	n/a	Heat2	Heat2	n/a
Cool2	n/a	Cool2	Cool2	n/a
Heat3	n/a	n/a	Heat3/Cool4	n/a
Cool3	n/a	n/a	Cool3	n/a
ModHeat	n/a	n/a	n/a	Modulating Heat
ModCool	n/a	n/a	n/a	Modulating Cool

The designation "n/a" means that the item may not be available for that sub-base configuration. The aux (auxiliary)

5 relay normal function may be one of the following: time of day occupancy signal, economizer enable, dehumidifier hot gas, and simple dehumidification. An additional stage of heating or cooling may be configured using the aux relay.

There may be two analog outputs available when Sub-baseMod

10 is used with the thermostat. Microcontroller internal timers may be used to generate a pulse width modulation output. A low pass filter on the sub-base may convert the pulse width modulated outputs to analog current. By connecting an appropriate value resistor, the output may be converted to

15 voltage output. The cycle time may be set at 8 MHz/200 counts (i.e., the frequency is 40 KHz and each counter pulse is 25 microseconds). The duty cycle may be set between 0 and 100

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percent.   There may be 200 steps in the 0 to 100 percent control

range.

Thermostat 11 may communicate with an external device such

as a Personal Digital Assistant (PDA), factory tester, PC based

5   development tool, or an optional communicating sub-base.   The

sub-base in turn communicates with other devices via a digital

data network.   There may be a software interface between the

thermostat and the external device, and the sub-base, including

the protocol, and the data structures.   There may be an external

10   device and the communicating sub-base connected at the same

time.   It is not necessary to communicate directly between the

sub-base and the external device.   There may be a need to

coordinate the communications flow from sub-base to thermostat

and from external device to the thermostat.   The object of the

15   interface may be to share information between the thermostat and

the external device (e.g., PDA) or between the thermostat and a

communicating sub-base using a simple low cost protocol.

Communications between the sub-base or external device, and

the thermostat may be via an asynchronous five wire connection.

20   The connections between the external device and the thermostat

may include an input to receive data (i.e., data flowing from

the sub-base or external device to the thermostat), an output to

transmit data (i.e., data flowing to the external device or sub-

base from the thermostat), an input for handshake (i.e., used to tell the thermostat that it is acceptable to send data to the external device), a pass-through connection (i.e., an external service request which may be used by the PDA to request access to the receive data. The latter connection may be between the external device and the communicating sub-base and only passes through the thermostat. There may also be a circuit ground connection.

Information may be passed between the thermostat and the external device using asynchronous characters having one start bit, eight data bits, no parity bit and one stop bit. The start bit is a logic 0 input (i.e., 0 volts) at the common hardware interface. The stop bit is a "logic 1" input (i.e., 3 volts).

The baud rate is 4800 baud. The maximum number of characters per message may be 11 characters. The limitation may be based on the fact that an entity that is exchanging information with the thermostat may not be able to process messages any larger than that at that rate.

The message format is shown below in table 33. The message may be 11 bytes long. The least significant bit of each byte is sent first. The "variable number" byte is the first byte sent and the "CheckSum" is the last byte sent. The same message format may be sent by the thermostat and the external device.

The message length is fixed so that the external device will be most efficient on using processor time resources. The processor may become inefficient if the message length is not the same as the length of the message it is expecting.

5

Table 33

Variable nr	1 to 8 data bytes	0 to 7 fill bytes	CheckSum

Figure 23 shows the elements involved in providing communications with an external device. "Share" is a structure

10 that may contain most of the thermostat global variables. Included in "share" may be configuration parameters, current status, and copies of inputs from the external device. "Share" may be broken into "variables" for transfer to/from an external device. In addition "other variables" may be included in the

15 list of variables shared with the external device.

The receive buffer may contain room for four received messages, the number of buffers currently in use, a pointer to the buffer being used to receive characters, a pointer to the next location to store a received character, and the value of

20 the partially calculated check sum.

The receive character interrupt routine may store characters into the receive buffer as they are received via the hardware UART one character at a time. A universal asynchronous

receiver/transmitter (UART) controller may be the key component

of the serial communications subsystem of the processor. The

UART may take bytes of data and transmit the individual bits in

a sequential fashion. At the destination, a second UART may re-

5   assemble the bits into complete bytes. The receive character

also may detect the start of the message using the gaps between

messages, calculate the checksum, update buffer pointer and

count when a valid message is received. If the buffer is full,

the receive character interrupt routine may ignore received

10   messages.

The send buffer may contain room for four received

messages, the number of buffers currently in use, a pointer to

the buffer being used to send characters, a pointer to the next

character to be sent, and the value of the partially calculated

15   check sum.

The send character interrupt routine may send characters

from the send buffer to the hardware UART one character at a

time. It also may calculate the check sum to send, put in four

character gaps between messages, and update buffer pointers as

20   messages are completely sent. When the send buffer is empty, or

the handshake line is not asserted at the end of a message, the

send character interrupt routine may turn it self off.

The handshake interrupt routine may run when the handshake line becomes asserted. If the send UART is turned off and there is data in a buffer, asserting the handshake line causes the first character of a ready send buffer to be sent via the UART.

5   The communications task may run every 100 milliseconds and perform the following communication tasks. First, if there are any messages in the receive buffer, it may reset the communications timer. If there are any messages in the receive buffer, it may copy them to their destination in local RAM

10   providing their class permits them to be copied. In 100 ms, it is possible to receive 3.2 messages. If there is any space in the send buffer, it may select the next variables to send to the external device and copy them to the send buffer until the send buffer is full. In 100 ms, it is possible to send 3.2 messages.

15   Receiving selected variables may cause a failure detect timer to be restarted. If a failure detect timer times out, the variables may be reset to a default value. Failure detect timers may be intended to provide fail safe operation of selected functions. If an inUse signal is received with the re-

20   programmer code, the communications task may turn off controlled equipment, save configuration parameters and user schedule in INFO flash memory, and call ProgramCodeFlash().

The alarmError signal may contain bits indicating that certain errors have been detected in the thermostat and may be viewed via the communication port. Table 34 shows the various alarm fields that may be used in testing and diagnostics.

5

Table 34

alarmError field	Meaning	What happens in the device on error	Method of displaying error on the device
almUsrScdCkSum	User Schedule Check Sum Error. Calculated when the user tries to retrieve the user schedule 0: User schedule was retrieved successfully 1: User schedule was not retrieved successfully	Current schedule continues to be used.	Display will not allow the user to select "yes" to retrieve the saved user schedule. It will display "no" when the user tries to change the selection to "yes"
almCnfPrmCkSum	Configuration Parameter Check Sum Error. Calculated when mains power is restored or upon a reset 0: Configuration Parameters were retrieved successfully from non-volatile memory. 1: Configuration Parameters were not retrieved successfully from non-volatile memory. The factory default configuration parameters are being used instead.	Factory default configuration is being used. almCnfPrmCkSum is set to zero when config1.installConfig is set to one by the installer.	No display action
almSub-baseType	Sub-base type error. Read from the sub-base resistive voltage divider in the sub-base 0: The sub-base is a valid sub-base type 1: The sub-base is not a valid sub-base type	Thermostat relays and analog outputs are turned off.	No display action
almIOConfig	Output configuration error. Considers sub-base type, heat pump / conventional application. maxCoolStgs, maxHeatStgs. 0: The outputs configuration is consistent with the sub-base type selected 1: The number of outputs configured exceeds the capability of the sub-base to support them.	In conventional mode, fan and only one stage of heating and cooling is enabled. If modulating sub-base is connected, modulation is activated. In heat pump mode, fan and only one compressor (heating or cooling) is available. Auxiliary heat is not available. Note: Modulating sub-base is not supported (All outputs turned off)	No display action
errDischSensr	Discharge sensor out of range or disconnected. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	Discharge air temperature limiting will not be done.	Display shows "- - -" for the value.
errRemtSetPt	Remote wall module set point is out of range or disconnected. 0: Value is OK. 1: Remote wall module set point is configured to function and is out of	Remote setpoint offset of zero (0) is used.	No display action.

10

	range or disconnected.		
errNetOdSensr	Network Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	There is no heat/cool lockout. The minimum heat/cool recovery ramps are used. See Note 1.	Display shows "- - -" for the value if the sensor is invalid. See Note 1.
errOdSensr	Remote Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no heat/cool lockout. The minimum heat/cool recovery ramps are used. See Note 1.	Display shows "- - -" for the value if the sensor is invalid. See Note 1.
errNetHumSensr	Network Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	There is no humidity control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
errRemtHumSensr	Remote Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no humidity control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errLoclHumSensr	Local Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no humidity control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errNetSpaceSensr	Network space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	There is no temperature control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errRemtSpaceSensr	Remote space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no temperature control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.
alarmError.errLoclSpaceSensr	Local space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	There is no temperature control. See Note 2.	Display shows "- - -" for the value if the sensor is invalid. See Note 2.

10   If a network sensor is configured for use, but invalid, then the thermostat processor may look for a valid sensor on the remote terminals. If it is valid it may use the remote as the value. If the remote is also invalid, it may look at the local

sensor. If it is valid it may use the local sensor as the

value. If all of them are invalid, then "invalid" may be

reported as the sensor value and the display will show "- - -".

This allows the user to configure the network (or remote) as the

5   primary sensor and have a backup in case the primary fails. If

the network sensor is configured and is invalid, it may report

an alarm error. If the remote sensor is configured and is

invalid, it may report an alarm error. If the local sensor is

configured and is invalid, it may report an alarm error. In

10   other words if the configured sensor is invalid, then it may

report an alarm error.

A factory test mode may be used to test the thermostat and

a connected sub-base. Components tested in the factory test

mode may include keys in the keypad (19 Keys), display segments,

15   four relays on the thermostat board, up to four relays on the

sub-base, one wall module LED driver, two Digital inputs (i.e.,

occupancy sensor and one wall module bypass push button switch),

two analog outputs (plus up to two analog outputs on the sub-

base where the modulating sub-base is required), eight analog

20   inputs (i.e., the local space temperature on thermostat, the

remote space temperature, the remote wall module set point

control, the local humidity sensor on sub-base, the remote

humidity sensor, the outdoor temperature sensor, the discharge

air sensor, and the sub-base identifier), and the communications
port (for data in, data out, and the handshake line).

The configuration parameters may be saved in INFO FLASH
memory when mains power has failed. There may be verification

5   that when mains power has been restored, the configuration is
also restored as saved. This may test the circuitry that senses
power failure and the power supply capacitors ability to supply
power for a few milliseconds while INFO FLASH memory is being
written.

10   The following may not necessarily be tested by the
software. One item is the super capacitor ability to supply
power to the device for the rated number of hours after mains
power has failed. Clock frequency may be another. A general
recommended approach to final factory test may be as follows.

15 Lock thermostat with sub-base into test fixture. Apply power
(24 volts AC – set voltage at low end of 24 VAC tolerance). The
display should initially turn on all segments after mains power
up. The test fixture may communicate with thermostat via
communications port and puts it into the factory test mode. The

20 test fixture may press the keys one at a time. Each key may
cause certain actions (e.g., provide a LDC display pattern, turn
on one relay, set the analog output to certain values, and so
on). A vision system may watch the display and reject units

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having an invalid display. The test fixture may sense digital

and analog outputs for proper operation. Simultaneously, the

test fixture may connect various analog sensors to the analog

inputs and monitors the sensed analog values via the

5   communications port. Simultaneously the test fixture may turn

on and off the various analog inputs and monitors the sensed

digital states via the communications port.

One may turn off the power. After 5 seconds one may cycle

the power back on. Then one may verify that, via the

10   communications port, the configuration was read correctly from

INFO FLASH memory into RAM upon power up. There is no need to

enter factory test mode. The display should initially turn on

all segments after mains power up. Turn off power and report

success or failure. Remove thermostat from test fixture. There

15   may be a separate test sequence or just one test sequence for

each sub-base type. Also, one may test the outputs and inputs

on the thermostat even if they are not present in the particular

sub-base type being tested.

To read and view the state of the inputs, one may read the

20   following variables via the communications port. The variables

may be read in the normal operating mode or in the factory test

mode. In the factory test mode, a filter is turned off so that

the analog value changes more rapidly in the factory test mode.

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Table 35 shows the various variables and what the typical test

values may be.

Table 35

Variable	Reads	Typical Values
rawAnalogA.remoteHum	Remote Humidity	14880 when input is 10.00 volts
rawAnalogA.localHum	Local Humidity	5460 when input is 1.00 volts
rawAnalogA.odTemp	Outdoor Temperature	13124 when input is connected to 3000 ohm resistor
rawAnalogA.discTemp	Discharge Air Temperature	3796 when input is connected to 10,000 ohm resistor
rawAnalogB.remoteStPt	Remote Set point	11228 when input is connected to 5500 ohm resistor
rawAnalogB.sub-baseSel	Sub-base Selection	8600 when input is connected to 10200 ohm resistor
rawAnalogB.remoteSpaceTemp	Remote Space Temperature	3796 when input is connected to 10,000 ohm resistor
rawAnalogB.localSpaceTemp	Local Space Temperature	3796 when input is connected to 10,000 ohm resistor
status1.occSensor	State of Occupancy Sensor	• TRUE when occupancy sensor input is shorted • FALSE when occupancy sensor input is open
status1.bypassTime	State of Remote Bypass	• Set to 180 minutes when the remote bypass input is shorted to ground. • Decrements every minute when the remote bypass input is open

5   To enter the factory test mode, one may set

manMode.manualMode to FactoryTest. In the factory test mode the

following may occur. The algorithmic control of the analog and

digital outputs is turned off. Instead, the outputs are

controlled by the internal factory test software. Every 15

10   seconds, manMode should be sent to the thermostat or the

thermostat will return to Run mode. The LCD and display no

longer function in the normal manner. Pressing a key pad button

may cause the following action. The output and pattern do not

change until another key is pressed.

15   One may verify that FLASH was written correctly upon mains

power fail. When mains power fails, the configuration

parameters and schedules are written to INFO FLASH memory as

soon as the power failure is detected. The successful writing

of INFO FLASH memory generally depends on the charge remaining

in the filter capacitors and the super cap.

During the write process at power fail, the following items

may occur. First, the check sum of the configuration parameters

5   is calculated. Second: the FLASH is erased. Third,

configuration parameters are copied into INFO FLASH memory, and

finally, the check sum of the configuration parameters

(including schedules) are written to INFO FLASH. Upon return of

mains power, if the stored check sum and the calculated check

10   sum agree, the configuration parameters are copied from INFO

FLASH into operating RAM. If the calculated and stored check

sums do not agree, then the factory default settings are copied

into the operating RAM. Also, if they do not agree,

alarmError.almCnfPrmCkSum is set to TRUE.

15   In the factory, when the device is first powered up, INFO

FLASH will not have any useful information stored in it, so the

calculated check sum will not agree with stored check sum, and

alarmError.almCnfPrmCkSum will be set to TRUE. However, when

the unit is powered down the first time, INFO FLASH may be

20   written correctly (assuming the power supply is working

correctly) and upon power up alarmError.almCnfPrmCkSum will be

set to FALSE indicating a successful writing of INFO FLASH. The

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factory tester should check alarmError.almCnfPrmCkSum after

powering the unit up the second time.

One may verify the microprocessor reset button. When the

reset button is pressed, the microprocessor will restart itself

5   and the display will temporarily turn on all its segments.

Other side effects may include such things as time is lost,

alarm bits reset, and all RAM status variables are reset to

their default values until the processor updates them to their

correct values. If the configuration or schedule has been

10   changed, the changes will be lost.

The manual mode is intended for field use. When the

thermostat is in manual mode, the equipment is controlled

manually via the communications port. Algorithmic control of

the equipment is turned off. The state of the eight relays is

15   controlled individually. The modulated heat and cool outputs

are controlled independently. Returning from factory test or

manual mode to run mode causes a reset.

The error count variable, errCnt, applies to the

diagnostics of the system. The errCnt.rxCkSumErrCnt may relate

20   to receiving messages from the PDA, tcomm, or the sub-base. The

message may include a check sum. Thermostat 11 may calculate

the check sum and compare it with the check sum in the received

message. The errCnt.rxCkSumErrCnt may be incremented every time

the calculated check sum does not match the received checksum.

Check sums may not match if the receiver receives a bit

incorrectly or if the start of message at the receiver was

received incorrectly. This count might be incremented once in a

5   while but the rate should be low, such as one or two counts in a

day.

The errCnt.rxBufferFullCnt relates to receiving messages

from the PDA, tcomm, or the sub-base. There may be a receive

buffer that has space for four received messages. Received

10   messages may be received using interrupts and placed into the

buffer. Once every 100 ms, the Comm. task may run, read the

messages and clear the buffer. If a message is received and

there is not enough space in the buffer for more messages, then

the message may be lost and errCnt.rxBufferFullCnt may be

15   incremented by one. The latter should always be zero. It takes

about 25 ms to send one message.

The errCnt.wdtCnt may be incremented if the program starts

over and the reason for the reset was a watchdog timer time out

(i.e., the program was lost and the watchdog timer caused a

20   reset). The errCnt.wdtCnt should always be zero. Failures may

occur due to hardware problems (e.g., reading memory

incorrectly) caused by electrical noise which is not very likely

because memory is on the same chip as the processor. Failures

may also occur due to a code that goes into an endless loop or a corrupted stack after a return from a subroutine call or the like. The watch dog timer may be "hit" once every 100 ms at the end of the tasks for each 100 ms time slot.

5   The errCnt.flashViolations may be incremented whenever there is a flash violation interrupt. Flash violation may occur if code is running from flash memory and tries to write the same flash memory module at the same time. The errCnt.flashViolations should always be zero. Flash writes may

10   occur during re-programming, power down, and update of user schedule.

Each display state is listed in the following table 36. A description for each state and a table listing actions for each key press follows. In general, a change of display state occurs

15   if a key is pressed or because no key has been pressed for a defined period of time and the information for the previous state is saved. Exceptions may be listed in the description for each state.

Table 36

State	Keypress	Description
dsRunNormal	keyRun	Display
dsHeatOcc	keyHeatOcc	Set Occupied Heat Setpoint
dsCoolOcc	keyCoolOcc	Set Occupied Cool Setpoint
dsHeatNotOcc	keyHeatNotOcc	Set Not Occupied Heat Setpoint
dsCoolNotOcc	keyCoolNotOcc	Set Not Occupied Cool Setpoint
dsSetDay	keySetDay	Set Day of Week
dsSetTime	keySetTime	Set Time of Day
dsTempOcc	keyTempOcc	Set Temporary Occupied Override
dsTempNotOcc	keyTempNotOcc	Set Temporary Not Occupied number of days
dsSetSched	keySchedDay, keySchedOcc, or	Set Schedules

State	Keypress	Description
	keySchedNotOcc	
dsSchedCopy	keySchedCopy	Copy schedule from one day to another
dsTempStpt	keyInfo, keyUp, or keyDown	Set Temporary Setpoint
dsInfo	keyInfo	Display Information screens
dsInstaller	keyRun and keySchedCopy	Set Installer configuration options
dsTestMode	keyRun, keySystem, and keyFan	Enter Test Mode (no delays of heating and cooling stages)
dsGetFactorySched	keyRun and keySchedClear	Restore factory schedules from flash memory to current schedules
dsGetUserSched	keyInfo and keySystem	Restore user defined schedules from flash memory to current schedules
dsSaveUserSched	keyInfo and keySchedCopy	Save current schedules to user define schedules in flash memory
dsFactoryConfig	keyRun and keySchedClear	Restore factory configuration
dsShowAll	Power up	Show all LCD segments for 2 seconds
dsShowLocked	---	Display 'LOCKED' or 'MANMODE' for 1 second

The test mode may be the dsTestMode. Pressing the combination key press ('scheduled day', 'schedule occ' and 'scheduled unocc) for 'Test Mode' may allow the user to disable

5   time delays between stages to minimize time to test the wiring and operation. The following information may be displayed: 'Set' segment -- 'NO TEST'.

Pressing the Up and Down keys may toggle the selection between 'IN TEST' and 'NO TEST' and save to the variable

10   share.sysMode.disabledelays. The 'IN TEST' will disable delays. 'NO TEST' is normal operation. After 10 minutes with no key pressed, the thermostat will change back to normal operation or 'NO TEST'. The following is the test mode table for the dsTestMode.

15   Table 37

Keypress	Actions:
keyNone	Increment NoKeyPressTimer. Change state to dsRunNormal after 5 minutes. Set share.sysMode.disableDelays to 'NO TEST' after 10 minutes.

Keypress	Actions:
keyDown	Toggle share.sysMode.disableDelays ('IN TEST' or 'NO TEST')
keyDown & keyHold	N/A

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keyInfo	Change state to dsInfo
keyUp	Toggle share.sysMode.disableDelays ('IN TEST' or 'NO TEST')

keyUp & keyHold	N/A
keyHeatOcc	Change state to dsHeatOcc

keyCoolOcc	Change state to dsCoolOcc
keyHeatNotOcc	Change state to dsHeatNotOcc

keyCoolNotOcc	Change state to dsCoolNotOcc
keySetDay	Change state to dsSetDay

keySetTime	Change state to dsSetTime
keyTempOcc	Change state to dsTempOcc

keyTempNotOcc	Change state to dsTempNotOcc
keySchedDay	Change state to dsSetSched Initialize sbDisplayDay to current day of week Initialize sbDisplayEvent to event Occupied 1

keySchedOcc	Change state to dsSetSched Initialize sbDisplayDay to current day of week Initialize sbDisplayEvent to event Occupied 1

keySchedNotOcc	Change state to dsSetSched Initialize sbDisplayDay to current day of week Initialize sbDisplayEvent to event Not Occupied 1

keySchedClear	N/A
keySchedCopy	N/A

keyRun	Change state to dsRunNormal.*
keyInstaller	Change state to dsInstaller.*

keySaveUserSched	Change state to dsSaveUserSched
keyGetUserSched	Change state to dsGetUserSched

keyGetFactorySched	Change state to dsGetFactorySched

*One may set the share.status1.bypassTime and share.status1.daysLeftKeypadHoliday to 0.

Thermostat 11 control algorithm may provide for control of various kinds of commercial HVAC equipment. More specifically it may be designed to control constant volume packaged roof top units used for single zone space temperature conditioning. A provision may also be provided to reduce humidity in the zone if it exceeds a high limit. Configuration parameters may allow for

the control to be for single stage, multistage or modulating

heating and cooling in conventional or heat pump units. The

control is capable of automatically switching between heating

and cooling as required if AUTO is selected as the run mode.

5 The fan and an auxiliary output may also be controlled depending

on configuration choices.

Figure 24 shows an algorithm module 200 overview. Algrm()

function 202 may be connected to timers and static variables

memory 204 via a two-way data path 203, and connected to a

10 share.status 1,2,3,analog memory 206 via a two-way data path

205. Algrm() function 202 may be connected to a Cycler()

function 208 via a one-way data path 207 towards Cycler()

function 208. Cycler() function 208 may be connected to timers

and static variables via a two-way data path 209. Algrm()

15 function 202 may be connected to a Set_outputs() function 210

via a one-way data path 211 towards Set_outputs() function 210.

Algrm() function 202 may be connected to an Aux_pt() function

212 via a one-way data path 213 towards Aux_pt() function 212.

Share.status 1,2,3,analog memory 206 may be connected to

20 Set_outputs() function 210 via a two-way data path 215, and

connected to Aux_pt() function 212 via a two-way data path 217.

Algrm() function 202 may be connected to TempControlInit()

and TempControlOff() functions 216 via a one-way data path 221

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towards functions 216. Algrm() function 202 may be connected to

an Auto_chng() function 218 via a one-way data path 223 towards

function 218. Share.config memory 220 may be connected to

Algrm() function 202 via a one-way data path 225 towards

5   function 202. Share.config memory 220 may be connected to

Cycler() function 208 with a one-way path 227 towards function

208. Share.config memory 220 may be connected to Aux_pt()

function 212 via a one-way data path 229 towards function 212.

Share.config memory 220 may be connected to Fan_Control()

10   function 214 via a one-way data path 231 towards function 214.

Share.setPts memory 222 may be connected to Auto_chng()

function 218 via a one-way data path 233 towards function 218.

Share.setPts memory 222 may be connected to Cycler() function

208 via a data path 235 towards function 208.

15   Cycler() function 208 may be connected to an ErrorCalc()

function 224 via a one-way data path 237 towards function 224.

A Share.auxSetPts memory 226 may be connected to ErrorCalc()

function 224 via a one-way data path 239 towards function 224.

ErrorCalc() function 224 may be connected to a Gain_Calc()

20   function 226 via a one-way data path 239 towards function 226.

A Share.gainHeat and Share.gainCool memory 228 may be connected

to Gain_Calc() function 226 via a one-data data path 243 towards

function 226.

Algrm() function 202 may be called every 10 seconds from the operating system task scheduler. It may read the commanded system mode and space temperature sensor input to arbitrate the effective run mode of thermostat 11. Also, the configuration

5 may be read to determine which control features to perform and the resultant "logical" control commands which are generated and written to the status RAM (random access memory) variables. The commands may be logical in that they generically list the run mode (heat or cool) and the number of stages of heat and cool

10 that should be active. A separate function called from the task manager may be responsible for reading the logical control output commands from status RAM and driving the physical outputs appropriately based on sub-base type and output configuration.

Looking further at the Algrm() 202 function overview, one

15 may note that if the manual mode command is factory test or manual, or the manual mode command is run and the system mode command is system switch = off, or the space sensor is invalid, then the logical control outputs may be set to initialization values and no other action is taken. If the manual mode command

20 is run and the system mode command is system switch = heat or cool, then Cycler() function 208 may be called with the effective mode set accordingly so that the proper set points may be used to calculate the space temperature error and its sign.

If the manual mode command is run and the system mode command is

system switch = auto, then Auto_chng() function 218 may be

called to calculate the proper effective mode (heat or cool) and

thus the proper set points before Cycler() function 208 is

5   called. After Cycler() 208 runs, then Set_outputs() function

210 may be called to take the Cycler() function 208 output and,

based on the configuration, set the control status variables

appropriately. Likewise, based on the configuration and the

Cycler() function 208 output status, the Fan_Control() function

10 214 and the Aux_pt() function 212 may be called to set their

logical output values per the control scheme selected. All the

timers associated with the control algorithm may be kept in this

function. These may be the four stage timers (one per possible

stage), the interstage timer, the start-up fan delay timer and

15 the dehumidify flag timer. When the disable delay ("test mode")

is selected, all of the control algorithm timers that delay

action may be kept cleared.

Cycler() function 208 may be implemented in the control

block diagram of Figure 25a. An output 245 from a set point 230

20 may go to a junction 232. An output 247 from a sensor 234 may

go to junction 232. Output 247 may be subtracted from output

245 at junction 232 to result in an error signal output (Err)

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249 which may go to the inputs of a "Kp/Ti $\int_0^t (Err)dt$" function block

236, a "Kp*Err" function block 238 and a "Kp*Td*(dErr/dt)"

function block 240. Outputs 251, 253 and 255 from function

blocks 236, 238 and 240, respectively, may be added at junction

5   242 to result in a total error (TotErr(%)) output 257 in terms

of percentage. Output 257 may go to a modulating driver 244.

Output 257 may go also to an input of a temperature

translation block 246. Block 246 may convert the total error

signal 257 from percent to a total error (TotErr(°F)) output

10   signal 259 in degrees Fahrenheit. Signal 259 may go to junction

248. In junction 248, a feedback signal 261 may be subtracted

from signal 259 resulting in a cycler error (CycErr) signal 263

which may enter an input of a hysteretic switch block 250.

Block 250 may output a "stages on" signal 265. Signal 265 may

15   go to an anticipator function block 252. Block 252 may output

feedback signal 261.

The temperature translation step may perform the function

of TotErr(°F) = TotErr(%)/100*AntAuth*stages. The purpose of

temperature translation 246 may be to turn the PID (proportional

20   integral differential) error in percent, which is used to drive

modulating outputs if they are present, into PID error in

degrees F which is the classic input into the multistage Cycler.

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This error in degrees F can now be added to the anticipator 252

accumulator, which is also tracked in degrees F. Now when the

Cycler Error (CycErr) 263 which is the PID Error plus the

anticipator 252 is fed into the hysteretic switch 250, the

5   classic cycling behavior of a thermostat may occur. Built into

this conversion may be the selected anticipator authority

(default of 4 degrees F per stage). The cycle rate constants

that are selected as part of the configuration are calculated

for the default anticipator authority (4 degrees F per stage)

10   only. Under most circumstances the anticipator authority will

not be changed, but under special circumstances changing the

anticipator authority may result in different cycling rates than

listed in the selections.

The anticipator function 252 may be Antic = Antic +

15   (stgs*AntAuth – Antic)*(1- e $^{-t/Tcph}$). It may provide for automatic

cycling by including a fictitious temperature error based on the

current number of stages active as follows: stgs = current

stages active set by the algorithm; AntAuth = anticipator

authority (heat per stage in deg F); T_{cph} = time constant

20   calculated to provide configured (cph) cycles per hr equipment

cycling rate; and t = time between calls of the Cycler()

function 208.

Cycler() function 208 may call ErrorCalc() 224 to obtain

the total PID error in percent, which may be limited to +/-200%.

It then may convert the percentage into degrees F by dividing by

100 percent and multiplying by 4 degrees F per configured stage.

5   The total error in degrees F may then be combined with the

standard anticipator 252 action before putting it through a

multistage hysteretic relay 250 function which drives the stage

logic.

In Figure 25b, output 257 may also go to an input of a

10   stager block 446. Stager block 446 may convert and

proportionally adjust the cycling rate for the digital stages,

and control the number of stages requested based on the

configuration of cycle rate, the number of stages configured,

sensed temperature, time delay minimum time and total error.

15   Output 465 of block 446 may provide a "stages on" signal for the

individual heating and cooling stages.

Along with the hysteretic relay output and/or minimum on

time, minimum off time and interstage delay times may also be

enforced before a stage is added or subtracted from the stages

20   active command that is the output of this function. This

function also may set the status of the dehumidify flag

(dehumidActive). It may use both a minimum on timer and a 5

percent hysteresis for turning off the flag once it is set. If

the sensed humidity is above the programmed high limit the flag

may be set.   Only after the humidity is 5 percent below the high

limit set point for the min on time will the flag be reset.   The

minimum on time may also be variable based on the occupancy mode

5   when the high humidity set point reset strategy is configured.

If the high humidity set point reset strategy is configured, and

the current occupancy mode is unoccupied, the dehumidActive flag

min on time may be 20 minutes; at all other times it may be set

to 5 minutes.

10   The ErrorCalc() function 224 may call the Gain_calc() 226

to convert the gain configuration parameters into the proper

units and fixed point offset to be directly used in the PID

error calculation.   It then may calculate the base PID error as

TotErr 257 in percent.   This may be used to drive the modulating

15   output if it is configured.   The secondary function performed

may be the discharge air limit function.   If the discharge air

limit function is active then if the discharge air is within 5

degrees F of the limit the TotErr is reduced proportionally down

to 0 as it approaches the limit.   If the discharge temperature

20   is over the limit, TotErr is set to 0, integration is stopped

and a flag is set to enable Cycler() 208 to turn off a stage and

prevent other stages from coming on.

Thermostat 11 may communicate with an external device 56

and an optional communicating sub-base 14. External device 56

could be a personal digital assistant (PDA) 12, factory tester,

or a PC-based development tool. Only one external device might

5   be connected at a time. Sub-base 14 in turn may communicate

with other devices via a digital data network. It may be

possible to have an external device 56 and communicating sub-

base 14 connected at the same time. There may be no need to

communicate directly between sub-base 14 and external device 56.

10   There may be coordination of the communications flow from sub-

base 14 to thermostat 11 and from external device 56 to

thermostat 11.

One object of the interface is to share information between

thermostat 11 and the external device (PDA) or between

15   thermostat 11 and a communicating sub-base 14 using a simple low

cost protocol. Communications between sub-base 14 or external

device 56, and thermostat 11 may be typically via an

asynchronous five wire connection. Figures 26 and 27 reveal

similar connections. The connections between external device 56

20   and thermostat 11 may include an input to receive data (i.e.,

data flowing from the sub-base or external device to the

thermostat) on line 301, an output to transmit data (i.e., data

flowing to the external device or sub-base from the thermostat)

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on line 302, an input to handshake (i.e., used to tell the thermostat that it is acceptable to send data to the external device) on line 303, and a pass through connection for an external service request (i.e., used by the PDA to request

5   access to the receive data) on line 304. The latter connection may be between external device 56 and communicating sub-base 14, and only pass through thermostat 11. Another connection may be a circuit ground on line 305. A 15 volt supply line 306 may be present. Lines 301, 302, 304 and 305 may be connected to

10   external device 56 via a connector 310.

Information may be passed between thermostat 14 and external device 56 using asynchronous characters having one start bit, eight data bits, no parity bit and one stop bit. The start bit is a logic 0 input (0 volts) at the common hardware

15   interface. The stop bit is a "logic 1" input (3 volts). The baud rate may be 4800 baud.

Data may be sent in both directions at the same time (a full-duplex operation). Thermostat 11 may receive data at any time. There may be thermostat transmitter flow control via

20   handshake circuit. Generally, data may be sent from thermostat 11 only when the handshake input is asserted. Communicating sub-base 14 may control the flow of data to it. External device 56 may send and receive at the same time. When external device

56 requests service by asserting an external service request,

communicating sub-base 14 may assert a handshake line 303 so

that the data may be sent continuously by thermostat 11. If

sub-base 14 is non-communicating, handshake line 303 may be

5   asserted continuously, so that an external device 56 may send

and receive data at the same time. Figures 26 and 27 show a

communicating sub-base 14 and a non-communicating sub-base which

is blanked out to indication non-functionality.

Thermostat 11 may receive flow control via an external

10   service request circuit line 304. Either communicating sub-base

14 or external device 56 may send data to thermostat 11 at any

time. However, both typically do not send data at the same

time. The external service request circuit via line 304 may be

used to select the active sender on the thermostat 11 receive

15   circuit.

When the external service request is not asserted,

communicating sub-base 14 may be allowed to communicate with

thermostat 11 in both directions, using the handshake circuit

via line 303 to control data flow from thermostat 11 to sub-base

20   14. When external device 56 asserts external service request

(using the RTS circuit on the external device's port) via line

304, communicating sub-base 14 may be allowed to complete the

message it is currently transmitting, before it asserts

handshake line 303 and ceases communications with thermostat 11.

External device 56 then may communicate with thermostat 11 in both directions until external device 56 unasserts the external service request. Note that sub-base 14 typically does not

5   listen to transmit data while external service request is asserted since handshake is also asserted. When sub-base 14 is a non-communicating sub-base, then external device 56 may still assert an external service request, and wait for at least one message time before sending on the thermostat 11 receive circuit

10   via line 301.

The handshake input to thermostat 11 microprocessor 61 may control whether or not thermostat 11 sends information to external device 56. When sub-base 14 is a non-communicating sub-base, the handshake input may be pulled to "active" by a

15   resistor on thermostat 11. Thermostat 11 may send information continuously on TXD of line 302, one message after another with the required gap between messages. When sub-base 14 is a communicating sub-base, the handshake input may be set to active by sub-base 14 whenever it is able to receive a message.

20   Thermostat 11 may send information on TXD line 302 whenever the handshake input is active.

When a communicating sub-base 14 is connected, then sub-base 14 may periodically send the sub-base variable to

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thermostat 11, with sub-base.connected = 1. An external device

56 may never send sub-base 14 to thermostat 11. This flag may

let an external device 56 know that a communicating sub-base 14

is present.

5   The inUse (i.e., in use) variable may be used to indicate

that an "inUse session" with an external device, a remote

network tool or network work station is in progress. The

inUse.by may also be used to initiate programming flash memory.

An "inUse session" may involve any of the following: an

10   external device (Palm Personal Digital Assistant) – inUse.by =

2; a read/write thermostat configuration using a PDA; a

read/write schedule using a PDA; a status report via a PDA

(optional at the discretion of the PDA designer); and manual

control via a PDA.

15   An "inUse session" may be started by either the external

device or the communicating sub-base when the other device

(i.e., a sub-base or external device) could interfere with a

process begun by the first device. The external device may have

priority over the sub-base. If a sub-base has initiated an

20   "inUse session", the external device may cancel the sub-base

session and initiate its own session. If an external device has

already established an "inUse session", the sub-base (and its

associated network tool) may not be allowed to start an "inUse session".

The external device located next to the thermostat should have priority over a network tool that may be located in another

5   room or even hundreds of miles away. Some related "inUse Session" scenarios may or may not involve some of the following examples. For instance, it may not be necessary for the external device to start an "inUse session" to just read any variables. It may not be necessary for the sub-base to start an

10   "inUse session" just to read any variables or write sub-base, comSchedOcc, comTimeIn, sysMode, or comIn. All of these variables may be either overhead variables (sub-base) or connected to some other network variables that may be bound to other devices.

15   It may be necessary for the external device to start an "inUse session" to read the varCONFIG variables, allow a user to modify them, write them to the thermostat, and then monitor their effects. That any time the PDA is connected to the thermostat, and the PDA is actively performing the Honeywell

20   Palm software, it should start an "inUse session" and set manMode to 0. The external device may start an "inUse session" by writing inUse.by = 2. Table 38 may provide more "inUse session details.

Table 38

inUse.by	Meaning	Communicating sub-base	External Device
0	Not in an "inUse session"	May send any variables to the thermostat.	Variables may not be sent to the thermostat except for inUse.
1	The remote network is in an "inUse session" with the thermostat via the communicating sub-base	May send any variables to the thermostat. Note: When nvilnUse (a network variable) is updated to non-zero by a network tool, and inUse is 0, then the sub-base writes, inUse.by =1.	Variables may not be sent to the thermostat except for inUse.
2	The external device (such as a PDA) is in an "inUse session" with thermostat	May send only varWRITE class variables to the thermostat (except manMode and inUse). Note: The sub-base sets nvilnUse (an e-bus mechanism variable) to 64129 when it sees that inUse.by is 2 to prevent a network tool from attempting to put the thermostat into manual mode or commission the device.	May send any variables to the thermostat.
3	The flash programmer is requesting to re-program the thermostat firmware	When the external device is the re-programmer, the sub-base may not send or receive any thing. The sub-base may re-program the thermostat using the re-programmer protocol.	External device uses the re-programmer protocol to down load the memory image. When the sub-base is reprogramming the thermostat, the external device should be disconnected or disabled.

5

Table 39 provides variable information relating to the alarm error system.

Table 39

Variable Description and Notes	VarNamefields.txt
User Schedule Check Sum Error. Calculated when the user tries to retrieve the user schedule 0: User schedule was retrieved successfully 1: User schedule was not retrieved successfully	alarmError.almUsrScdCkSum
Configuration Parameter Check Sum Error. Calculated when mains power is restored or upon a reset 0: Configuration Parameters were retrieved successfully from non-volatile memory.	alarmError.almCnfPrmCkSum

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1: Configuration Parameters were not retrieved successfully from non-volatile memory. The factory default configuration parameters are being used instead.	
Sub-base type error. Read from the sub-base resistive voltage divider in the sub-base 0: The sub-base is a valid sub-base type 1: The sub-base is not a valid sub-base type	alarmError.almSub-baseType
Output configuration error. Considers sub-base type, heat pump / conventional application. maxCoolStgs, maxHeatStgs. 0: The outputs configuration is consistent with the sub-base type selected 1: The number of outputs configured exceeds the capability of the sub-base to support them.	alarmError.almIOConfig
Discharge sensor out of range or disconnected. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errDischSensr
Remote wall module set point is out of range or disconnected. 0: Value is OK. 1: Remote wall module set point is configured to function and is out of range or disconnected.	alarmError.errRemtSetPt
Network Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	alarmError.errNetOdSensr
Remote Outdoor air sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errOdSensr
Network Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	alarmError.errNetHumSensr
Remote Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errRemtHumSensr
Local Humidity sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errLoclHumSensr
Network space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function but is not being updated by the network	alarmError.errNetSpaceSensr

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Remote space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errRemtSpaceSensr

Local space temperature sensor not working. 0: Sensor value is OK. 1: Sensor is configured to function and is out of range or disconnected.	alarmError.errLoclSpaceSensr

The thermostat configuration may be identified and then the commissioning process may be run through valid operational modes

5   with inputs and set points temporarily manipulated while waiting for the delays built into the controller to verify operation. The PDA based Online Diagnostics may automatically discover the thermostat configuration, turn off normal controller delays, temporarily override sensor inputs and set points, verify proper

10   output action including monitoring the discharge air temperature for the resulting temperature behavior based on the equipment stages activated.

Problems discovered may be reported, automatically recorded and the original operating parameters may be restored. This

15   means that less expertise may be required by the technicians sent to install and trouble shoot thermostat installations

To begin the commissioning startup, the user may tap on the commission button on a PDA screen as shown in Figure 28a. The next screen may prompt the user to connect the PDA 12 serial

20   port to thermostat 11, as in Figure 28b. Then the configuration

tool (i.e., PDA 12) may upload the thermostat model and current configuration from the thermostat. A commission summary screen appears as revealed in Figure 28c. This screen may appear after an analysis of the thermostat configuration. Navigation through

5   the commissioning process by the user may be accomplished with the "Back" and "Next" buttons. The diagnostics may be executed in a logical order of sensors, fan/auxiliary process, cooling process and heating process. The status of each step of the diagnostics process may be reported as "OK", "UnTested" or

10   "Failed". An error summary may report known problems (via thermostat diagnostic messages) and summarize all session related messages.

The "Next" button may navigate the user to the sensors screens shown in Figures 29a-29f. In Figure 29a, the sensors

15   screen may summarize the status of sensor/input diagnostics. Sensor data may be displayed in a context sensitive format using the actual thermostat model and configuration data to mask irrelevant sensor tests. Of the buttons on the screen, the "Update" button may update sensor data values, "Back" button may

20   navigate to the previous screen, "Next" button may navigate to the "Fan" screen, and the "Test" button may initiates the automatic sensor diagnostics test sequence.

As a result of tapping the Test button on the sensors

screen, one may get a reading testing the room temperature data

value which may be confirmed or not by tapping the "Pass" or

"Fail" button on the screen of Figure 29b, respectively. As a

5   result of tapping the "Testing Room Temp" Pass button, the

diagnostics may move to the remote SetPoint test sequence, which

begins with the screen in Figure 29c. The user may tap the "OK"

button after positioning the remote SetPoint knob to the full

CCW position. As a result of tapping the Testing Remote SetPt

10   OK button, the diagnostics tool may validate the Remote SetPt

value at full CCW, as indicated in the screen of Figure 29d.

Then one may be instructed to position the remote SetPoint knob

to the full CW position. As result of tapping the Testing

Remote SetPt OK button, the diagnostics tool may validate the

15   Remote SetPt value at full CW. Then the user may tap the OK

button in the screen of Figure 29e to proceed with remaining

sensor diagnostics. In a similar fashion, all of the sensor

inputs may be validated. At the end of the sensor diagnostics

sequence, configuration tool 12 may indicate the status of all

20   relevant (hardware model and user configuration) sensors, as in

the screen of Figure 29f. All Error messages may be recorded on

the diagnostics summary screen.

The user may tap the Next button to navigate to the

Fan/Auxiliary screen of Figure 30. The Fan/Auxiliary Equipment

screen may summarize the status of the Fan/Aux output

diagnostics. Output data may be displayed in a context

5   sensitive format using the actual thermostat model and

configuration data to mask irrelevant output tests. Tapping the

Update button may update the data values. The Back button may

navigate the user to the previous screen. The Test button may

initiate the automatic Fan/Aux diagnostics test sequence. The

10   Next button may navigate the user to the first cooling screen in

Figure 31a.

The Cooling Equipment screen may summarize the status of

the cooling output diagnostics. Output data may be displayed in

a context sensitive format using the actual thermostat model and

15   configuration data to mask irrelevant output tests. In this

screen the Update button may update data values, the Back button

may navigate to the previous screen, the test button may

initiate the automatic Cooling diagnostics test sequence. The

Next button may navigate the user to the Heating screen. In

20   Figure 31b, the screen asks whether it is safe to start the fan.

And if so, then the Yes button may be tapped and a screen of

Figure 31c may appear. The user may tap the Test button on this

screen and confirm that the fan is running by tapping the Pass

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button. The next screen to appear may be that of Figure 31d,

asking if it is safe to start the cooling stages. The user may

tap "Yes" to confirm that it is safe to start the cooling

stages. The screens of Figures 31e and 31f may appear,

5   respectively. Here, configuration tool 12 may collect and

analyze data. The data collected may include the time interval

on the progress line, the entry and discharge air temperatures

over the time interval and the cooling coil delta temperature

which may be the difference between the coil entering and

10   discharge air temperatures. After this process, tool 12 may

validate the cooling stage under test as in the screen of Figure

31g. All of the remaining stages may be likewise checked out.

Figure 31h shows a completion of the cooling equipment

validation.

15   Tapping the Next button, one may get the Heating Equipment

screen of Figure 32a, which may begin with the check-out of the

heating stage 1. The Heating Equipment screen may summarize the

status of heating output diagnostics. Output data may be

displayed in a context sensitive format using the actual

20   thermostat model and configuration data to mask irrelevant

output tests. On this screen, the Update button may update data

values, the Back button may navigate the user to the previous

screen, and the Next button may navigate to the summary screen.

The Test button may initiate the automatic heating diagnostics test sequence, which may start with the screen in Figure 32b. The user may tap "No" to indicate that fan airflow is not required for stage 1 heating. Such airflow may be typical for

5 baseboard heat installations. The next screen may be that in Figure 32c asking whether it is safe to activate the heating stage contact. The user may tap "Yes" to confirm that activation. That heating stage may be turned on, which is indicated by the screen of Figure 32d. After checking to see in

10 the heating stage is actually on, the user may then tap "Pass" to validate the stage 1 heating. A screen of Figure 32e may next appear indicating that the heating tests have been completed. Wiring and connections between the controls and fan, heating, cooling, air flow process, interfaces and other items

15 may be tested and validated.

Figure 33 is a flow diagram of an illustrative diagnostic test sequence for a thermostat system. In block 351, one may connect PDA 12 to thermostat 11 and upload the configuration identification as in block 352. The normal controller delays

20 may be turned off as in block 353. Block 354 shows the sensor inputs and set points being overridden. Then the sensors may be tested and the set points checked in block 355. The fan/auxiliary process may be tested in block 356. The cooling

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process may be tested in block 357 and the heating process may be tested in block 358. Then the noted failures, errors and dysfunctions of thermostat 11 may be displayed on PDA 12 as in block 359. In block 360, diagnostic solutions may be presented.

5   Although the invention has been described with respect to at least one illustrative embodiment, many variations and modifications will become apparent to those skilled in the art upon reading the present specification. It is therefore the intention that the appended claims be interpreted as broadly as

10   possible in view of the prior art to include all such variations and modifications.